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JOURNAL OF ANATOMY

THE GROWTH OF THE LONG BONES IN FOETAL LIFE, AS EXEMPLIFIED BY A CASE OF FOETAL SYPHILIS

By H. A. HARRIS, M.B., B.S., D.Sc.

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The experiments of both Hunter and Duhamel on the growth in length of the long bones of pigs and birds showed that there was no intercalated growth in the diaphysis and that all growth in length took place by apposition of new bone on the diaphysial side of the epiphysial cartilage. There is no justification for the statement of Macewen (1): "Interstitial growth occurs in the diaphysis of long bones, contributing slightly to increase of length." Accordingly it is essential that no opportunity should be lost of placing on record any case which confirms the early observations of Hunter and Duhamel, both of whom, as Sir Arthur Keith (2) has pointed out, have been unfortunate in their commentators.

A mother was admitted to the ante-natal clinic with a history of four previous pregnancies. The first yielded a full-time child now alive and well. The second resulted in a babe born near term, but death supervened at the seventh month. During this pregnancy the mother had a cutaneous rash, sore throat and syphilitic sores for which she received intravenous antisyphilitic medication. The third and fourth pregnancies terminated in the abortion of premature macerated foetuses. When seen during the fifth pregnancy the mother presented a positive Wassermann reaction and was placed on active antisyphilitic treatment consisting of the intravenous injection of novarsenobenzol over a period of eight weeks. A still-born foetus was delivered at the thirty-sixth week.

The radiograms of the bones of the still-born babe (Plate I) show the progress of the disease in the embryo in a unique manner. All the bones display evidence of arrested growth (3). The ilium in particular shows that bone formation had proceeded normally for a period of about 22 to 24 weeks as judged by the size of the innermost zone of homogeneous bone. This was followed by a dense line of bony deposition, about 1 mm. wide, indicating a definite period of acutely arrested growth. The line of arrested growth was followed by a zone 3 to 4 mm. wide in which the trabeculae are but poorly differentiated. This zone of poorly differentiated bone is followed in turn by a dense line of arrested growth, the deposition of which occurred in the weeks immediately preceding death.

The series of changes so clearly seen in the ilium are similarly recorded in the long bones and even in the centra of the vertebrae. In all the bones there is distinct evidence of normal bone growth for the first half of pregnancy.

The line of arrested growth immediately following probably corresponds to the onset of toxic symptoms due to the syphilis. The zone of poorly differentiated bone laid down in the following weeks shows that failure of active osteogenesis and excessive formation of fibrous tissue which is characteristic of chronic infection. The terminal line of arrested growth immediately preceding birth may be due to a summation of the effects of the syphilis and novarsenobenzol or to the effect of either singly.

The radiograms offer definite evidence in support of many of the facts known to the pathologist. The embryo or foetus shows no gross manifestations of congenital syphilis before the fifth month of intrauterine life. This is probably due to the fact that the placenta is not permeable to the spirochaete of syphilis or its toxins until it has already commenced those degenerative changes in the way of endarteritis, fatty degeneration and calcification which normally commence at the end of the fifth month. There is no evidence that the foetus ever displays gross lesions of any infectious disease, transmitted from the mother, previous to the initiation of the processes which lead to placental infarction. It is also of interest that osteo-chondritis syphilitica of the new born and also lines of cessation of growth due to the administration of toxic doses of phosphorus and arsenic were both described in the first place by Wegner(4) as far back as 1874.

From the point of view of the growth in length of the long bones the radiogram affords a striking parallel to the work of John Hunter with madder fed to the growing animal. In this case the spirochaete, by reason of the faulty bone laid down under its influence, not only shows the region of deposition, but clearly shows the amount of growth at each end of the respective long bones. Even in the case of the metacarpals and phalanges the radiogram indicates which is the more rapidly growing end. The first metacarpal is seen to conform in type to a first phalanx.

(*Note.* Since the demonstration of the above case Dr McNee has called my attention to a similar case recently described by Pick(5) of Berlin.)

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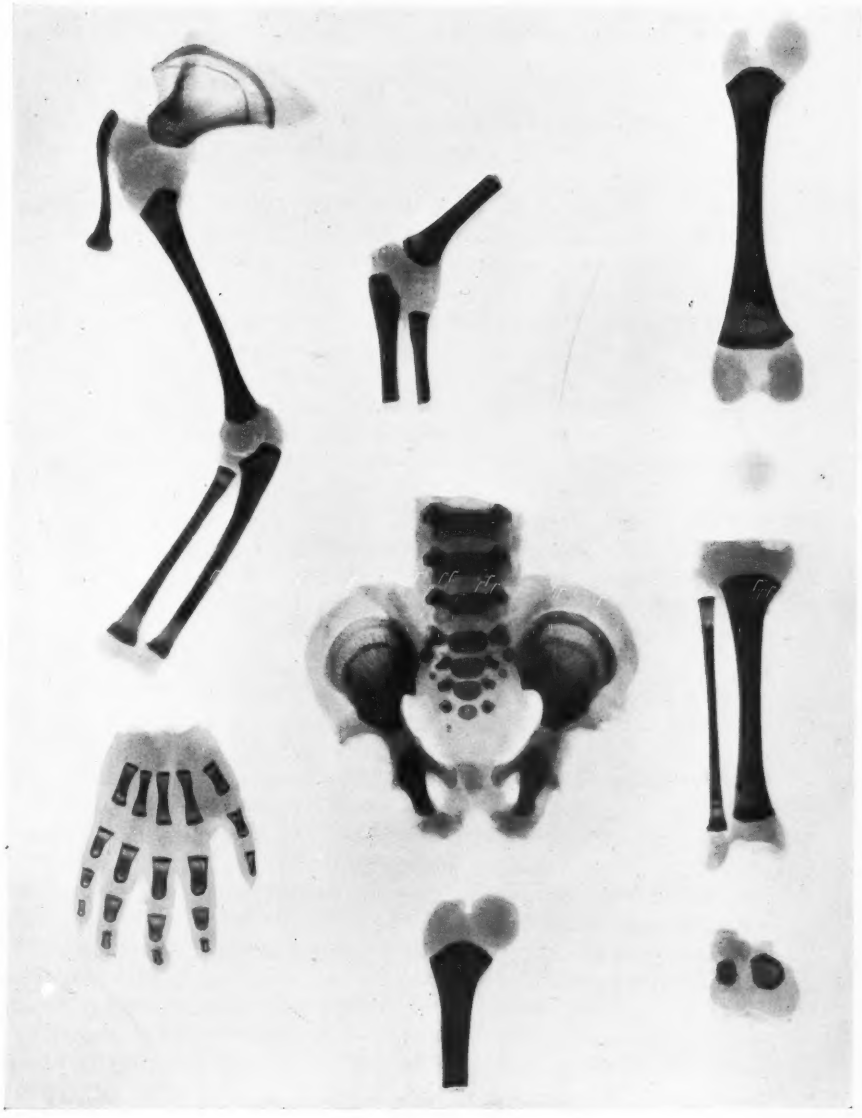
DESCRIPTION OF PLATE I

Radiograms of the bones of a congenital syphilitic foetus of 36 weeks. Note the dense lines of arrested growth laid down in the sixth and ninth lunar months and the intervening zone of imperfect bone formation.



THE VASCULAR SUPPLY OF BONE, WITH SPECIAL REFERENCE TO THE EPIPHYSIAL CARTILAGE

By H. A. HARRIS, M.B., B.S., D.Sc.

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The problem of the blood supply to the region of the epiphysial cartilage of the long bones is of the greatest importance in relation to disease of this area during the period of active growth. It is all the more imperative that the truth of the older experiments should be vindicated in view of the fact that the erroneous observations of Lexer, Kuliga and Türck(1) have displaced these experiments from most of the recent text-books of surgical pathology. William Hunter(2), as far back as 1742, as a result of a series of injections of the arteries to the limb, described his "circulus vasculosus articuli." This circulus articuli was not only the arterial supply to the joint and the intra-articular structures, but also the supply to the epiphysis in relation to the capsule of the joint.

Lexer and his co-workers injected the limb arteries of the new-born babe with quicksilver and they depict anastomoses between the arterial fields of the diaphysis and epiphysis traversing the epiphysial cartilage. Accordingly a series of injections of the limb arteries were made in actively growing animals and still-born babes with carmine gelatine at pressures well within the physiological range. No anastomoses were seen between the vessels of the diaphysis and epiphysis. The drawing of the upper end of the femur of a young dog (Plate I) and the drawing of the lower end of the femur of a still-born babe (Plate II) indicate the condition seen. The former specimen was cleared in oil of winter-green and carefully examined under the binocular microscope. The latter was examined in section by indirect illumination. In each case the vascular territories of the epiphysis and diaphysis are distinct and no vessels penetrate the growth cartilage.

The vessels of the diaphysis are virtually "end arteries," with but a poor anastomoses between the territories of the respective end arteries. Thus the phenomena of disease in the juxta-epiphysial zone or metaphysis are essentially phenomena of infarction. And infarction of bone differs in no essential manner from infarction in other organs supplied by end arteries, such as the lung, liver, spleen, kidney and brain. It is this infarction of a wedge of bone, the base of which abuts on to the epiphysial cartilage which determines the radiographic appearance of a lesion in the metaphysis of the long bones. It is this infarction which militates against the diagnosis of a bony lesion in terms of radiographic appearance alone.

Although the epiphysial and capsular lines do not accurately coincide at the ends of the long bones, the capsular line having progressed or regressed in accord with the modification of the position of the limb and the migration of muscular attachments, yet it is important to stress that naked-eye examination of the fresh bone gives direct evidence of the changes produced in the bone in the neighbourhood of the capsular and epiphysial lines. The portion of the epiphysis of the femur which lies outside the capsule presents the surface appearance of the shaft or diaphysis, and is lightly pitted with very small vascular foramina. On the other hand, the portion of the diaphysis which lies within the capsule presents the surface appearance of epiphysial bone and is deeply pitted with numerous large vascular foramina. Thus the diaphysis and the portion of the epiphysis which lies outside the capsule have a high degree of osteogenesis, whereas the epiphysis and the portion of the diaphysis within the capsule have but a small power of osteogenesis. These variations in the power of repair are displayed by those fractures involving the knee and hip which at the same time as they are either intracapsular or extracapsular may yet involve epiphysial bone and diaphysial bone to varying extents. The troublesome intracapsular fracture of the neck of the femur is a fracture of a portion of the diaphysis which has adopted to a considerable extent the mode of nutrition and osteogenetic power of the epiphysis. The clinical aspect of this problem will be discussed in detail elsewhere.

In conclusion, the older views of the blood supply to the region of the epiphysial cartilage stand confirmed. Vessels penetrating the epiphysial cartilage are not seen in the growing animal except in the case of pre-existing disease leading to failure of proliferation of the epiphysial cartilage as in acute arrest of growth; in chronic disease of the area as in osteo-chondritis syphilitica; and in that delay of union of the epiphyses which is sometimes seen at the end of adolescence, rarely in Man, but more frequently in certain domesticated and wild animals. In the actively growing healthy animal the epiphysial cartilage is avascular and presents the typical mode of growth of a vegetative tissue as seen also in a cancer, fibroid, gumma or tubercle.

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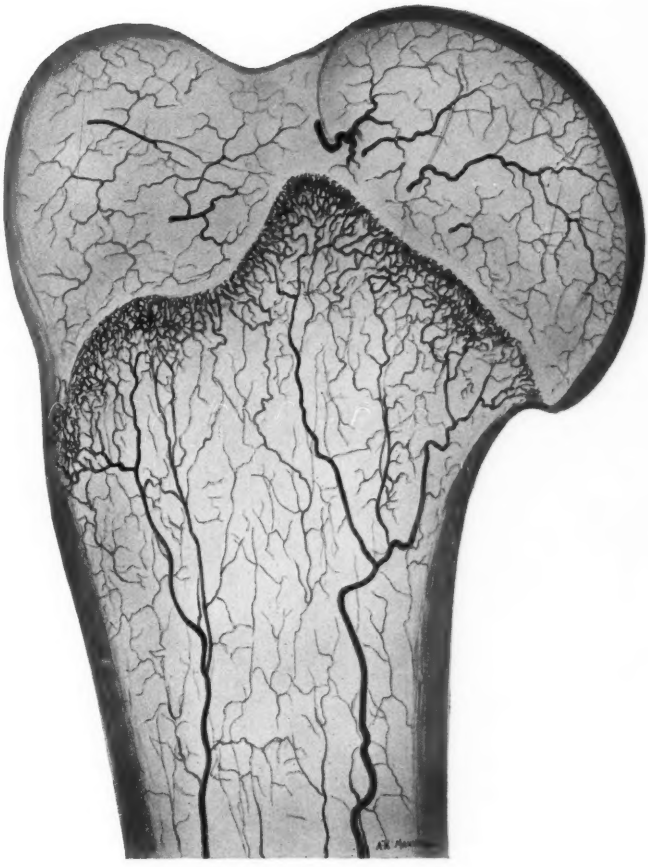
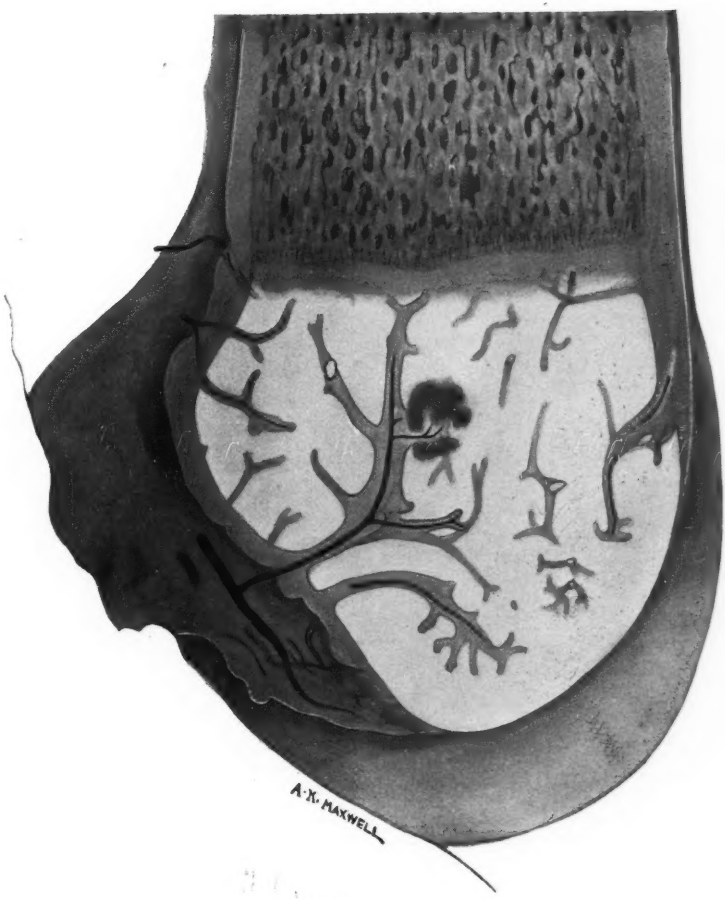
DESCRIPTION OF PLATES I AND II

Plate I. The upper end of the femur of a pup showing the avascular epiphysial cartilage of the head and great trochanter. The vessels are injected with carmine gelatine and the specimen cleared with oil of winter-green.

Plate II. The lower end of the femur of a still-born babe in section. The arteries are injected with carmine gelatine. Ossification has commenced in the epiphysis.




A. K. MAXWELL

THE HISTOLOGY OF THE RETAINED TESTIS IN THE HUMAN SUBJECT AT DIFFERENT AGES, AND ITS COMPARISON WITH THE SCROTAL TESTIS

By EUGENIA R. A. COOPER, M.D., M.Sc.
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THE object of this research was to compare the structure of the normal and retained testes in childhood, with a view to establishing whether changes in the latter glands were primary or secondary. Moreover, it was hoped that the results would enable one to decide whether or not it was justifiable to advocate transplantation of the retained gland in infancy, with a reasonable prospect of its complete development when placed into its natural environment.

During the past few years, great interest has centred around the ectopic testis in man and animals, and much valuable work has been done by Crewe (6, 7), Bland-Sutton (4), Turner (38), Bevan (2), Moore (21–29), Thorek (35–37), Lipschutz (20), Fukui (11), Hobday (14), Bissonnette (3) and Eccles (9).

It appears to be generally agreed that undescended testes in later life are functionless as regards spermatogenesis. It is still controversial, however, whether the imperfection is primary, or secondary and dependent upon the persistence of the malposition.

TECHNIQUE

The glands examined were all subjected to the same histological technique, so that a standard was maintained, and influences due to different methods were obliterated.

All adhering connective tissue was removed until the tunica albuginea was reached. The glands were cut into three parts, *A*, *B* and *C*, by two incisions transverse to the long axis, the upper one passing through the centre of the globus major, the lower one through the body of the epididymis. Thus the upper, middle and lower parts of the testis were available for easy examination, and also the three parts of the epididymis.

The retained organs were obtained from the operating theatre and fixed immediately, post-mortem changes being thus overcome. The scrotal glands were necessarily removed at autopsies, but they were fixed as soon as possible, and post-mortem changes were reduced to the minimum.

The number of retained testes examined was unavoidably small, since, with modern operative technique, the majority of the organs are now trans-

planted into the scrotum rather than excised. (Twelve retained testes were obtained and a series of 36 scrotal organs was used for comparison.)

All organs were fixed in 10 per cent. aqueous solution of commercial formalin. Fresh sections of Block *C* were cut by the freezing microtome and stained with Sudan III and haemalum. Blocks *A* and *B* were embedded in paraffin and all sections cut at 6 μ. Three methods of staining were adopted:

(i) Haemalum and aqueous eosin, for general observations.

(ii) Mallory's Säure-fuchsin phospho-molybdic acid stain for connective tissue.

(iii) Heidenhain's iron haematoxylin method for special cytological observations.

OBSERVATIONS

During the last two months of human intra-uterine life the testis is situated somewhere between the posterior abdominal wall and the scrotum, usually completing its descent before birth in a full-time foetus. Normally by the seventh month the testis in the human subject has attained a position at the internal abdominal ring (16), or has entered the inguinal canal. The gland examined at this age was oval in shape and of small size. The epididymis was situated above and posteriorly to the testis and was freely movable, being attached above only by a small rete testis to the upper pole of the gland, and otherwise separated from it by a wide digital fossa, measuring about 0·3 cm. at its widest point. The vas deferens emerged below from the globus minor.

Histologically the organ was surrounded by a delicate fibrous tunica albuginea which projected into the gland at one point, forming the mediastinum or hilum testis. The connective tissue of the hilum was continuous with that of the digital fossa, and from it fibrous strands radiated into the testis forming a fine meshwork supporting the tubules. The supporting tissue throughout was of a delicate nucleated nature, except the more peripheral parts of the tunica albuginea, where more mature fibres were observed. The arrangement of the supporting elements was found to be similar at all subsequent ages, except that as age advanced coarser fibrous tissue replaced the delicate nucleated material. No further reference will be made to this point.

At this age the testis consisted of small tubules measuring about 42 μ in diameter (Pl. I, fig. 1[1]). They were loosely arranged, the intervening intervals being filled by delicate fibres. There was no definite fibrous basement membrane, but the nucleated connective tissue was condensed around each tube. The tubes were entirely filled by closely packed seminiferous cells, the majority presenting the same appearance—a round, pale, oval nucleus, exhibiting definite nuclear membrane and spots, embedded in an ill-defined mass of cytoplasm. The nuclear spots, arranged irregularly within the membrane,

[1] Diameters represent the mean taken from measurement of 10 circular tubules in true transverse section.

represented the chromatin reticulum. These cells are best described as undifferentiated germinal epithelium cells (19). The nuclei of these cells present differences in their affinity for stains. It is probable that one type would differentiate into cells of Sertoli, and the other into spermatogonia. At this age no definite cells of Sertoli were present.

Frequently, with lower microscopic powers, some cells seemed to have "escaped" from the tubules, but this appearance was due to the accumulation of the nuclei of the delicate stroma round the tubes.

In many of the tubes, one or more larger cells were present, consisting of a large, round, deeply stained nucleus lying in the middle of a big, round cell body, of which the cytoplasm was sometimes pale and ragged, but often definite and well stained. The nuclear membrane was distinct, and several dark nuclear spots, representing the chromatin, were arranged just inside the membrane. These cells were differentiated spermatogonia and were always present in the peripheral parts of the tube (Pl. I, fig. 1).

Throughout the testis, in the intertubular tissue, small accumulations of large polygonal cells were observed. The protoplasm was finely vacuolated, presumably due to the removal of fatty material in the course of the histological preparation. The cell outlines were often indistinct and the mass appeared syncytial. The nuclei were well stained and larger in size than any of those of the tubular cells, and each contained usually two nucleoli. These cells were the interstitial cells of Leydig and were present in large numbers in all parts of the gland. They presented a similar appearance throughout life.

In section, the epididymis was of the same size as the testis. It consisted of round, empty tubes lined by a single layer of ciliated columnar epithelium. The tubes were isolated by delicate fibrous tissue continuous with that of the digital fossa, and more compact immediately around each tube. No further reference will be made to the epididymis, as no alterations, beyond increase in the number and size of tubules, were observed.

The earliest age at which the retained testis was examined was fourteen months, and this gland was situated in the right inguinal canal near the external abdominal ring. It was approximately equal in size to the normal organs of the same age. The digital fossa was open, an interval of 0·45 cm. separating the body of the testis and the epididymis, whilst a stalked appendix (vas aberrans) was suspended from the lower pole of the testis (Pl. I, fig. 2 A).

Normal glands examined during the first two years of post-natal life often presented an open digital fossa, and a vas aberrans was not rare (Pl. I, fig. 2 B). It was repeatedly noticed, in both scrotal and retained testes, that a persistent digital fossa was frequently accompanied by a vas aberrans.

In sections of this retained testis a tunica albuginea of moderate width surrounded the organ. The tunica, mediastinum testis, and digital fossa all consisted of delicate fibrous tissue. The tubules were closely packed and equal in size to those of the scrotal glands of the same age, measuring 65 μ in transverse section. Each tube was enveloped in a well-defined basement membrane.

In the centre of the gland, coarser fibrous tissue separated the tubes, indicating a commencing fibrosis (Pl. I, fig. 3 B). The greater number of tubules were filled with cells, but there was a tendency for them to become arranged in rows against the basement membrane, the centre being empty or containing more loosely arranged cells. Most of the cells had a similar appearance, and were identical with the undifferentiated cells of scrotal testes (Pl. I, fig. 3 A).

As in the normal testis, the nuclei showed a differential staining. One or two larger cells were present in each tube, resting on the basement membrane. These were the spermatogonia, and were in all respects similar to those of scrotal glands.

Here and there a small group of interstitial cells was observed in the intertubular intervals. The epididymis in all parts was characteristic in appearance.

Towards the end of the second year the scrotal testes examined were found to vary considerably, both anatomically and histologically. Some were characterised by the patent digital fossa and the presence of a vas aberrans. In others the testis and epididymis were in contact and there was no appendage.

Histologically, glands of the former series showed a reversion to the earlier condition. The supporting tissue was embryonic. The tubes were isolated and devoid of a true basement membrane. They were of small size, measuring 46 μ in section. Two or more spermatogonia were present in each tube. The rest of the cells were undifferentiated, often presenting a syncytial appearance. There were no interstitial cells.

Testes of the second series were in all respects similar to the glands described as characteristic for this period. The supporting elements were truly fibrous, and a definite fibrous basement membrane surrounded each tube. The tubes were closely packed and measured 50 μ. They were filled with undifferentiated cells amongst which were two or more spermatogonia. In the latter were some very large nuclei probably preparing to undergo division *in situ* (Pl. I, fig. 3 A).

Thus it will be seen that the retained testis of fourteen months was a compromise between two types of scrotal organs occurring at this age. Whilst the histological elements conformed to the type characteristic of this period, the anatomical details were similar to those of scrotal glands of younger age. The slight thickening of the intertubular connective tissue in the retained organ was the only distinguishing feature.

The retained testis obtained from a child of two and a half years was situated high up in the right inguinal canal. Its dimensions were all smaller than those of a completely descended testis of the same age. It was accompanied by a large patent processus vaginalis. The epididymis was curious. It was in close contact with the testis posteriorly, the digital fossa being almost closed. Above, it was only loosely attached to the upper pole of the gland, and was then prolonged downwards, hanging freely over the anterior margin of the testis. Histologically this testis was enclosed in a delicate

fibrous tunica albuginea of similar width to that of the scrotal gland of the same age. The tubes were scattered irregularly throughout the gland; at the periphery they were closer together, whilst in the centre they occurred in small groups widely separated by delicate nucleated supporting tissue. There was the appearance of cells having "escaped" from the tubes, but on closer examination these cells were seen to be part of the nucleated intertubular stroma which was condensed in the vicinity of the tubes. This feature was observed in the foetal testis (Pl. I, fig. 4).

There was evidence of a commencing fibrosis in the centre of the gland, but so far the tissue was of a delicate texture. The tubules were of small size, measuring in transverse section 57 μ. Each was enclosed within a fine but definite basement membrane. The tubes were more or less filled with cells, the majority of which were undifferentiated epithelial cells. In the minority of tubes, definite spermatogonia were present, two or three or more occurring in one tubule. On the whole the spermatogonia were proportionately less numerous than in the scrotal testis of the same age, even considering the reduction in the number of tubules in this retained gland. The spermatogonia present, however, were similar in all respects to those in completely descended glands. An occasional small group of interstitial cells was recognised, possibly indicating that the organ had developed more slowly than was normal.

Scrotal testes in the third year again presented anatomical variations. In a few, there was an open digital fossa and a vas aberrans. In the remainder, the fossa was closed and there was no appendage. The tubules were closely approximated throughout the organ, being separated only by their basement membranes. They measured 62 μ in diameter. Three or more large spermatogonia were present in each tube projecting into the lumen amongst the undifferentiated cells.

Comparing the retained testis from a child of two and a half years with scrotal ones of the same age, it will be seen that there were distinct alterations. There was a reduction in the number and size of the tubules, and an increase in the intervening stroma. The tubular cells, however, were characteristic in appearance though not in numbers.

A testis retained at the internal abdominal ring was obtained from a child of four years. It was similar in size to a scrotal gland of a child aged five and a half years. The globus major and minor of the epididymis were in contact with the upper and lower poles of the testis respectively, but the body was separated from the posterior margin of the testis by a wide digital fossa measuring 0·5 cm. at its widest point. A tiny vas aberrans was suspended from the lower end of the testis.

In the centre of the gland there was a considerable thickening of fibrous tissue, and amongst it were small isolated tubes, each supported by a delicate fibrous basement membrane. At the periphery, the tubes were similar in arrangement, but fine nucleated connective tissue occupied the intertubular intervals. The diameter of the tubes was 46 μ. Most of them contained a

single or double layer of cells lying inside the basement membrane, but some were filled by cells. The cells were undifferentiated, the nuclei again presenting a differential staining. The limits of the protoplasm of each cell were ill-defined. The majority of tubules contained one or more typical spermatogonia. In a few, a double nucleus was observed. No interstitial cells were seen in this testis.

Another testis retained in the higher part of the inguinal canal of a child of four and a half years was examined. In size this gland was similar to the one described above. The digital fossa was closed. Histologically the organ consisted of small tubes scattered evenly throughout the gland. The intertubular tissue in all parts was of a fine nucleated character, forming concentric rings round each tubule, the basement membrane not being definitely formed. In transverse section the tubes measured 38 μ. Each contained closely packed undifferentiated cells lying in rows at the periphery of the tube. Many of the tubes contained one or more large characteristic spermatogonia. No interstitial cells were recognisable in this gland. The epididymis called for no special description.

Another testis retained at the internal abdominal ring in a child of five years was obtained. The tunica albuginea was wide and composed of very delicate nucleated stroma. The tubules measured 38 μ, but were not numerous (Pl. I, fig. 5). They were irregularly arranged in groups throughout the organ, and delicate fibrous tissue occupied the intervals between them, becoming more concentrated around each tube. There was no distinct basement membrane. Typical undifferentiated cells were gathered into two or three rows at the periphery of the tubes, the centre being empty. Some tubes contained two, three or four spermatogonia resting against the basement membrane amongst the undifferentiated cells. The spermatogonia were of large size and characteristic in structure. The scrotal testes examined during the fifth year were found to be comparatively small in size, showing no increase on those of the fourth year. The digital fossa was closed in all cases. The tubules were closely approximated throughout the organ, and were small, measuring 50 μ on an average. They contained undifferentiated cells, usually accumulated near the basement membrane. Spermatogonia were present. Some of them contained a double nucleus, probably resulting from recent division. Interstitial cells were absent. Comparing the retained testes obtained from children between the ages of four and five years with scrotal ones, it will be seen that in the former there was a great reduction in the number of tubules. The variation in size was not so apparent, since in the normal glands the size was variable. The fibrosis in the centre was confined to the retained organs. Although the tubular cells were collectively reduced in the latter, their histological structure was characteristic.

An undescended gland obtained from a child of six years was abdominal in situation. It was of larger dimensions than scrotal glands of that age, and all parts of the epididymis were removed from the testis (Pl. II, fig. 6 A). The

digital fossa between the body of the epididymis and the testis measured 1·4 cm. A vas aberrans was suspended by a long stalk from the lower end of the epididymis. A wide fibrous tunica albuginea surrounded the organ, and dense fibres invaded the peripheral parts of the testis. Within the tunica the interstitial tissue was of a delicate nucleated nature, and immediately around each tube became more compact, forming three or four concentric rings. The basement membrane was not distinctly formed.

The tubes were of small size and scattered unevenly (Pl. II, fig. 6 B). In transverse section they measured 46 μ. At the periphery of the testis and near the hilum the tubules were more numerous, but in the central parts they were separated by wide intervals occupied by a fine meshwork of fibres. The tubes contained irregularly arranged cells, the majority of which were undifferentiated. Some of the tubes, especially those near the tunica, contained one or more larger cells, similar in all details to spermatogonia. Although they were absent in most of the tubes, yet as many as five were counted in a single tube.

No cells of Leydig were observed in the intertubular tissue. The epididymis was in no way different from that of scrotal testes. Unfortunately scrotal testes from children between the ages of six and seven were not obtained.

One examined from a child of eight years showed a reversion to an earlier type (Pl. II, fig. 7). It was composed of scattered tubes of small size measuring 50 μ in section. The intertubular tissue was of an infantile, nucleated character, though more mature fibres formed the basement membranes. The tubes were irregularly distributed, being in closer contact near the mediastinum than elsewhere.

Undifferentiated cells were arranged in the peripheral parts of the tubes, the centre being empty. Three or four or more spermatogonia were present in each tube, many showing signs of nuclear division *in situ*. As yet no cells of Sertoli as described by Winiwarter (41) and Allen (1) were distinguishable.

Comparison of the abdominal retained testis of a child of six years with a scrotal gland of a child of eight years, showed that a reversion to a more primitive type (characterised by a smaller number and size of the tubes and a greater amount of interstitial stroma) is not confined to the retained gland, and may occur even in scrotal organs.

No retained testes were available between the ages of seven and twelve years. The normal glands examined during this period were found to increase greatly in size, attaining adult dimensions about the thirteenth year (Pl. II, fig. 9). The tubules in these cases were closely packed, separated only by their basement membranes. In one gland from a child of eleven years, there was a persistent digital fossa and a vas aberrans. The tubules in this case measured only 50 μ, and were again separated, the intervals being occupied by delicate stroma. Two or more spermatogonia were present in each tube, some containing a large nucleus, and others a double nucleus resulting from recent division. At this period occasional interstitial cells were recognisable in the intertubular spaces.

In all the organs examined from the tenth year onwards to puberty, a noticeable change occurred in some of the undifferentiated cells. Instead of the innumerable chromatin spots in all parts of the nucleus, as in the true undifferentiated cells, the background of the nucleus was pale, and one to four definite nucleolar spots of variable size lay irregularly inside the nuclear membrane. They occurred either separately or in pairs, near the periphery of the nucleus or in the centre. The protoplasm was of a fine reticulated nature, indistinguishable from that of the ordinary undifferentiated cells, being syncytial in both cases as far as could be ascertained in post-mortem material. The nuclei of some of these differentiated cells corresponded very closely to those described as characteristic of cells of Sertoli by Regaud (34), Winiwarter (41) and Allen (1). It is probable that this nuclear differentiation indicated a further stage in the development of cells of Sertoli.

An imperfectly descended testis was obtained from the right inguinal canal of a child of thirteen years. In size it corresponded to scrotal glands of the same age. Unlike these organs, however, the digital fossa was still open, the body of the testis and epididymis being separated by an interval of 0·8 cm. A large vas aberrans was suspended by a long stalk from the globus minor.

Histologically a fibrous tunica albuginea of normal width surrounded the testis. The parenchyma of the gland consisted of tubules of similar size to those of a scrotal testis at puberty, measuring 92 μ in diameter (Pl. II, fig. 8). Each was enclosed within a well-defined basement membrane, but the intertubular intervals were occupied by delicate connective tissue fibres. The tubes were in contact with one another in the peripheral parts of the testis, but were more widely separated internally. They contained cells lying in two or three layers against the basement membrane, leaving an empty central lumen. Three types of cells were recognisable:

1. Many were of the undifferentiated type.
2. Large characteristic spermatogonia.
3. Many cells were differentiated into characteristic cells of Sertoli.

The undifferentiated cells usually occurred against the basement membrane, while the differentiated ones were more internal.

A striking feature of the tubes of this gland was the large number of big spermatogonia present in each. Often the small tubular cells were hidden by the germ cells (Pl. II, fig. 8).

Numerous groups of interstitial cells were seen in the intertubular tissue. Compared with scrotal glands of this age, these cells did not seem to be in excessive numbers. The epididymis was histologically similar in all respects to that of the ordinary adolescent glands.

Another retained gland, from a subject of thirteen years, was of extraordinarily large size. It was abdominal in situation. As in some of the other retained testes, the digital fossa was open, and measured 1·5 cm. approximately in width. A large stalked appendix was suspended from the lower pole of the testis where it lay in contact with the globus minor.

In section this testis consisted almost entirely of fibrous tissue. A very wide tunica albuginea enveloped the organ, but was of a coarser fibrous nature than that in the centre. The limit of the tunica was recognised by the change in the character of the fibrous tissue, and by the presence of a ring of tubules arranged in small groups round the periphery of the gland. Here they were closely approximated, but the central parts contained only an occasional tube. The tubes were surrounded by a definite basement membrane, and they presented a peripheral accumulation of cells. They measured 49 μ in transverse section. The majority of cells were specialised forms of undifferentiated cells, and corresponded to those described as cells of Sertoli. Only a few typical spermatogonia were recognisable, and were not present in the majority of the tubes. In the interstitial tissue between the tubes, groups of typical cells of Leydig were seen. It was significant to find that they occurred only in the intertubular regions of the gland. The epididymis called for no special description.

A scrotal testis obtained from a child of twelve years was of large size, and anatomically similar to the fully developed organ (Pl. II, fig. 9). The tubules of the gland measured 90 μ in diameter, and throughout the organ were evenly distributed and in close contact with one another. Each was enveloped by a fibrous basement membrane. The tubules all exhibited an irregular empty central lumen, with two, three or four layers of cells around it. Large, typical spermatogonia were present in all the tubes, resting against the basement membrane. Many showed a double nucleus, the result of recent division, and the newly formed spermatogonia were smaller in size and contained a small, darkly stained nucleus.

Active nuclear division of the spermatogonia was visible in the majority of tubes. Spermatocytes were differentiated, and their nuclei showed all stages of fragmentation. Spermatids and spermatozoa were not recognisable. A large number of undifferentiated cells had by this age undergone complete differentiation into cells of Sertoli, characterised by their large pale nuclei and cell body of ill-defined limits, in contrast to the active nuclei of the germinal cells. Many interstitial cells were present in groups in the intertubular angles.

At thirteen years the testes examined were approaching adult dimensions. The digital fossa was "closed," although the thin outer margin of the epididymis could be raised from the testis and a finger inserted into the fossa. The tubes were of large size measuring 114 μ in transverse section, and each was separated from its neighbours by its basement membrane. Spermatogonia were present in the tubes resting against the basement membrane. More internally were the spermatocytes, the nuclei of which presented all stages of mitotic division. An additional stage in the development of the germinal cells was seen in some of the tubes. This consisted of a small, round or oval, darkly stained nucleus in a small amount of cytoplasm. These were spermatids, and were always near the centre of the tubule. As yet there were no spermatozoa.

As in the testis of twelve years, differentiation of the small primitive cells was indicated by the change in the nucleus, which exhibited two distinct nucleoli, instead of a "véritable poussière" of chromatin spots which characterised the early undifferentiated cells. In many tubes the mitotic changes in the germinal cell nuclei were not apparent, and in those cases the differentiated forms of the undifferentiated cells were very obvious. The arrangement of the protoplasm and the distinctive nucleus rendered these cells indistinguishable from the cells of Sertoli. Regaud (34) and Allen (1) state that they never observed true cells of Sertoli until spermatids had formed.

Another type of scrotal testis was found at the thirteenth year. Histologically it belonged to an earlier type. The tubes were of comparatively small but variable size, and were in contact. They contained closely packed cells amongst which were spermatogonia resting against the basement membrane. These cells showed variations in their nuclei, some being large in size and ready to divide, others smaller and probably resting. Only occasionally was there any mitotic change in the germinal cells. The other tubular cells were either undifferentiated, or definite cells of Sertoli. Groups of large syncytial interstitial cells were present in the intertubular angles in all parts of the organ.

Thus a testis retained in the lower part of the inguinal canal in a boy of thirteen years presented many features in common with a scrotal one of the same age. For instance, in both cases, cells of Sertoli were differentiated, but, on the other hand, mitotic changes in the germinal cells were not observed. The testis of this age retained in the abdomen showed marked fibrosis. In this gland and in the one retained in the inguinal canal the three types of tubular cells (undifferentiated, spermatogonia and cells of Sertoli) were present and similar to those of the scrotal organs, though perhaps reduced in number.

A retained testis was obtained from a person of fifteen years. It was situated just inside the left internal abdominal ring, and was accompanied by a patent processus vaginalis. It was of large size, and the epididymis was separated from the testis by a wide interval, occupied by fibrous tissue. The organ was surrounded by a thickened fibrous tunica albuginea, and was composed of large tubes measuring 121 μ in diameter, all isolated by delicate, vascular stroma, and surrounded by a well-marked fibrous basement membrane. The tubes were not characteristic of the age, for they contained comparatively few cells, showing no nuclear activity (Pl. II, fig. 10). They were aggregated in two or three rows against the basement membrane, whilst the large central lumen was occupied by strands of protoplasm prolonged from that surrounding the nuclei. In some of the smaller tubes, loosely arranged syncytial cells filled the lumen.

The cells were in many cases degenerated, but some were characteristic cells of Sertoli. Only an occasional spermatogonium was seen, but those present were in the resting condition. Large groups of interstitial cells occupied the intertubular intervals. These cells appeared to be in excessive

numbers, but compared with scrotal glands of the same age, this richness was only apparent, the cells of Leydig being more conspicuous on account of the wide separation of the tubes.

Scrotal testes examined at puberty between the fourteenth and sixteenth years had assumed adult characteristics. The tubules in these cases were of large size, measuring 137 μ in diameter in transverse section. They were closely approximated and evenly distributed throughout the gland. Each was enclosed within a basement membrane. Between the tubules there was finer connective tissue in which groups of interstitial cells were discerned.

Active spermatogenesis was observed in many of the tubes, whilst others appeared to be in a resting condition. Next to the basement membrane were spermatogonia alternating irregularly with definite cells of Sertoli, which exhibited the characteristic nucleus and nucleolus. The cytoplasm of the cells of Sertoli was syncytial and vacuolated, large round empty spaces occurring irregularly within it. The protoplasm of the spermatogonia, however, was usually of clearly defined limits, but often overlapped and obscured by that of adjacent cells of Sertoli. Simple undifferentiated cells were frequently seen resting immediately against the basement membrane.

Nearer the centre of the tubes were the spermatocytes, the nuclei of which showed different stages of fragmentation. In the most internal parts were spermatids, usually in small groups. They were distinguished by their small, round, well-stained nucleus and well-defined mass of protoplasm. Often they formed an isolated mass in the lumen of the tube.

Lastly, spermatozoa were present, consisting of a lance-shaped head and filamentous tail. Many appeared to have lost their tails, possibly a result of post-mortem autolysis. As a rule, different stages of spermatogenesis were seen in different parts of the same tube, and usually the spermatozoa, with their heads buried in the syncytial cytoplasm of Sertoli cells, were accumulated in parts where only the nurse cells were present.

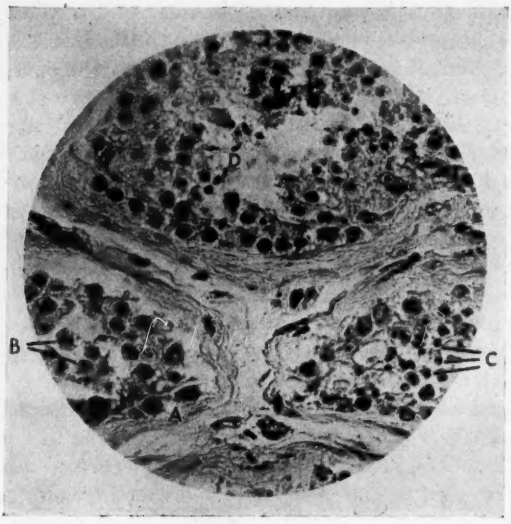
Small groups of typical interstitial cells were recognised in the intertubular angles.

The retained testis examined at puberty showed marked changes including the absence of spermatogenesis which normally characterises this period.

A retained testis was obtained from a dissecting-room subject aged sixty years. The gland was equal in size to the right scrotal gland of the same subject. The retained testis was situated on the front of the pubes at the external abdominal ring, and it was fixed to the posterior wall of the scrotum by a strong strand of connective tissue. The globus major surmounted the upper pole of the testis, whilst the body and globus minor of the epididymis lay across the centre of the left aspect of the organ, the vas deferens being posterior.

Microscopically the testis was found to be enclosed within a very wide tunica albuginea composed of tough fibrous strands. Many tubules were present, some of which were healthy, though many were atrophied. Long

columns of healthy, active tubules alternated with degenerated tubes or with parallel strands of vascular fibrous tissue. The atrophied tubes were elongated and narrow, and were surrounded by a delicate basement membrane. Within the tubes were cellular remnants and a few odd nuclei, whilst very fine fibres formed a meshwork in which the cell débris and nuclei were enmeshed. The healthy tubes were elongated and of a large size, and each was surrounded by a greatly thickened basement membrane (text-fig. 1). The tubes were occupied by germinal cells, showing all stages in their maturation. In many tubes



Text-fig. 1. Tubules of testis retained at external abdominal ring, age 60 years. *A*, spermatogonia. *B*, spermatocytes. *C*, spermatids. *D*, spermatozoa. × 350.

definite spermatozoa were recognised by their elongated, very deeply stained heads. They were usually buried in the vacuolated protoplasm of a cell of Sertoli. The tails of the spermatozoa were not recognisable, on account of post-mortem autolysis, since the statutory four days elapsed after death before the body was injected with preservative fluid.

Small groups of polygonal interstitial cells were present in the spaces between both healthy and degenerated tubes.

It was interesting to trace the course of the duct of this retained testis, as, according to Bland-Sutton (4), no account has been given of the vas of retained testes in cases where otherwise the genitalia were normal. It so happened that in this instance, the vas on both sides took an abnormal course. Having passed down the side wall of the pelvis to the ischial spine, it turned acutely inwards to gain the upper border of the seminal vesicle,

passing *underneath* the ureter, which was sharply bent forwards at the ischial spine to enter the bladder. Otherwise the course and termination of the vas were similar to normal cases.

I am indebted to Prof. West of the University of Cardiff for sections of a retained testis of a subject of thirty-eight years. The small glandular mass was removed from the inguinal canal during the operation for radical cure of an inguinal hernia. The patient was a hermaphrodite, presenting a condition of hypospadias, and had lived as a female subject.

The organ was rounded and measured 4 mm. in diameter. It was surrounded by a thick fibrous tunica albuginea from which very vascular strands of connective tissue entered the gland. The testis consisted of small scattered tubes, measuring 114 μ in diameter, each surrounded by a thickened fibrous basement membrane. In places the tubes were widely separated by large vascular strands, or by masses of interstitial cells. Inside the tubes were a few cells, irregularly arranged, some against the basement membrane, others projecting into the cavity, and others lying freely within the lumen of the tube. The cells, with two exceptions, in half a dozen sections examined, presented a similar appearance. Each consisted of an oval or rounded nucleus, of a homogeneous staining reaction, containing usually one large dark nucleolus and frequently a smaller one. As a rule a small amount of fine protoplasm surrounded the nucleus and there was no distinction between the protoplasm of adjacent cells. Judging from the histological condition of the nucleus, it seems justifiable to consider these cells as cells of Sertoli.

In one tubule, one cell of a different kind was observed amongst the cells of Sertoli. It consisted of a well-stained, round nucleus, with a sharply defined nuclear membrane, against which were arranged several small nuclear spots, whilst the central part of the nucleus was paler. Around the nucleus was a small amount of reticulated protoplasm. Compared with the tubular cells in the normal testis, it seems possible that this cell was a spermatogonium (text-fig. 2 A).

In another tubule a cell of large size was seen, in marked contrast to the cells of Sertoli present around it. It consisted of a big, round nucleus surrounded by a well-defined round mass of clear protoplasm. The nucleus was delicately stained and its chromatin reticulum was in the form of a long filament folded several times on itself. It seems reasonable to consider this cell as a spermatogonium attempting to undergo nuclear activity (text-fig. 2 B).

Large syncytial masses of typical interstitial cells occurred throughout the section. The epididymis was of similar size to the testis in section and its structure was in no way different from the normal, except that the tubes contained no testicular secretion.

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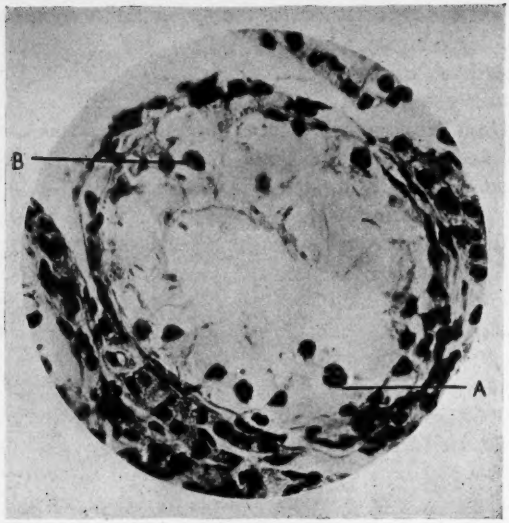
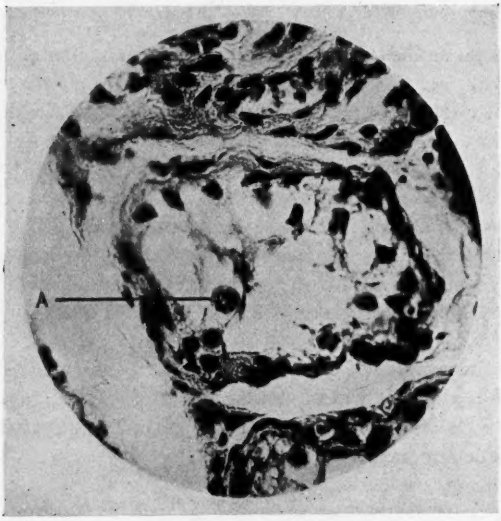


Text-fig. 2 A. Testis of a hermaphrodite of 38 years. *A*, nucleus of a spermatogonium. *B*, nucleus of a cell of Sertoli with characteristic nucleolus. × 500.



Text-fig. 2 B. Testis of a hermaphrodite of 38 years. *A*, nucleus of a spermatogonium apparently undergoing division. × 500.

SUMMARY

From a survey of the findings in the scrotal testes of different ages in childhood, it appears that although the testis increases in size progressively, the development of the organ may sometimes be retarded. This arrest of development is characterised by the isolation of the tubules, the increase of the interstitial tissue which appears in the form of embryonic nucleated stroma, and the diminution in the size of the tubes. The germ cells, or spermatogonia, seem in some cases to be correspondingly reduced in number. Sometimes the digital fossa is open as in foetal glands.

Looking at these details from another point of view, it is suggested that there may be no arrest in the formation of the tubes, but that the organ is growing in bulk by an increase in the amount of embryonic stroma, and the formation of new and smaller tubes from pre-existing ones. The increase in stroma occurs to accommodate the newly formed tubes which, in their turn, will become larger, on account of the proliferation of the tubular cells, and will ultimately come to be in contact with one another. Mott (31) describes a similar arrest of development during the third year, but in this present research the gland at this age appeared to be growing rapidly.

From foetal life until the tenth year only two types of cells are present in the tubes—spermatogonia and undifferentiated cells. It is believed that the former are developed from the latter, although with the histological methods available, no stages in the transformation could be recognised. In nearly all the glands examined, however, there was a differential staining of the nuclei of the undifferentiated cells, suggesting that one type may ultimately become spermatogonia, and the other develop into true sustentacular cells. It seems certain, however, that spermatogonia are able to divide *in situ* and reproduce like cells.

From the tenth year onwards, a further differentiation of the undifferentiated cells is clearly recognisable. The characteristic nucleus with innumerable chromatin spots becomes replaced by a paler one with one or two distinctive nucleoli. A similar nucleus in syncytial protoplasm is described as characteristic of the cells of Sertoli by Winiwarter (41), Allen (1) and Regaud (34). At the twelfth year, when spermatogenesis is proceeding, it seems justifiable to regard the specialised undifferentiated cells as true cells of Sertoli, as they are similar in all respects to those occurring in testes where spermatids are present. Regaud (34), whose views are supported by Allen (1), states that the first appearance of the nuclei of Sertoli cells in the seminal epithelium coincides, in the rat, with the differentiation of spermatids.

In a gland at the thirteenth year, examined in the course of this research, where spermatogenesis had not commenced, the Sertoli type of nucleus was clearly observed in all the tubes. In all cases, the protoplasm of purely undifferentiated cells, of the specialised undifferentiated cells, and of true cells of Sertoli, was syncytial as far as could be ascertained. Allen (1) and

Regaud (34) describe the Sertoli tissue as syncytial, but Winiwarter (41) states that by studying serial sections, he was forced to conclude that the cells of Sertoli were not syncytial, since he could demonstrate a well-defined base and long cell body. This author and Regaud (34) believe that the cells of Sertoli and spermatogonia come from a common source. The results of the present research also point to the same conclusion. Regaud (34), however, was unable to find any transition forms during the differentiation of these two elements from their parent stock, and Winiwarter (41) never found any traces of nuclear division in the adult cells of Sertoli.

The appearance and disappearance of the interstitial cells is a remarkable feature in the human testis. They are present in large numbers during foetal life and until the fourth month after birth. Then, with close approximation of the tubes, the interstitial cells practically disappear and remain in abeyance until the tenth year. They then reappear and gradually increase until possibly their maximum numbers are attained at puberty, after which time they persist throughout life. Mott (31) found numerous interstitial cells in the testis of a newly born child, but at the fourth month they were decreasing rapidly. Whatever their origin, it is interesting to note that, between the ages of five months and ten years, few or no cells with any resemblance to interstitial cells are recognisable in the interstitial tissue.

Apparently the cells of Leydig are influenced by factors other than normal physiological phenomena of birth and puberty, for certain workers (11, 18, 24, 39) describe a hyperplasia of these cells during various experimental investigations on the testis in animals. It appears that the cells of Leydig are an important source of lipoid material in the human subject. The cortex of the suprarenal gland is another source of lipoid, and it is significant to note that it is most active in the production of lipoids during early post-natal life and at puberty (5), probably necessitated by the rapid development of the brain at the former period, and of the maturation of the sexual glands at adolescence. There is, in both the suprarenal and testis, a phase of comparative arrest of lipoid production between these two periods. At present it is not possible to state how far the two organs are associated with one another in this lipoid-producing function, or to what extent they are dependent on each other.

DISCUSSION AND CONCLUSIONS

From a study of the retained testis in childhood at different ages and in different situations, and comparison with scrotal testes of similar ages, it seems justifiable to draw the following conclusions:

1. The further the pre-adolescent testis has descended in its normal route, the more closely does it correspond, histologically, to the scrotal gland of the same age.

This conclusion is similar to that of Moore (23), who remarks, after experimental elevation in animals of the testis into the abdomen and later causing its return to the scrotum: "In general it may be stated that the more nearly a testis returns to its normal scrotal position, the more nearly normal will be the tubular epithelium." Hunter (15) believed that the abdominal retained testis was probably more defective than those late in getting into the scrotum.

It appears from recent work by Crew (6), Fukui (11), Moore (21–29) and his co-workers, and Bissonnette (3), that the all-important factor for the full development of the testis and maturation of the spermatozoa, is the presence of the gland in the scrotum. Fukui (11), Crew (6) and Moore (21–29) seem to have proved conclusively that the low temperature of the scrotum is essential for complete spermatogenesis. Thorek (37) has stated that the young ectopic testis is not seriously compromised, and that transplantation into the scrotum has been followed by good functional results. Bissonnette (3), after examination of the high-flanker testis in cattle, concludes that "only descent into the scrotum, either natural or artificial, or other means of cooling the organ, appears to make spermatogenesis possible." According to Moore (23), "the scrotum exerts a peculiar influence upon the testis, and an influence which is necessary not only for the complete differentiation of the germ cells, but for the retention of cells previously differentiated."

If the position of the gland in the scrotum is the all essential factor, then, realising that the condition of the retained testis in childhood is healthy, it is justifiable to surmise that such organs will complete their development if placed artificially into the scrotum.

In this research, one gland found in a man of sixty years at the external abdominal ring showed in parts complete spermatogenesis; two others found in the lower part of the inguinal canal in children aged fourteen months and thirteen years, showed features characteristic of pre-adolescent scrotal glands; others situated in the upper part of the inguinal canal presented a reduction in the amount of parenchyma, but a healthy condition of the existing essential elements; other testes occurring in the abdomen were affected by different degrees of fibrosis, and a greater reduction in the germinal elements, but amongst those persisting, a few healthy forms were present.

Hobday (14) states that it is not rare to find spermatozoa in testes which have remained in the lower part of the inguinal canal, but in those found in

the upper part or in the abdomen this is exceptional. One case of complete spermatogenesis, including spermatozoa formation, was found by Bland-Sutton (4), who believes that the retention of a testis is due to its imperfection (*vide* Hunter (15)): Bland-Sutton (4) also states that a healthy testis is never found in the inguinal canal. It appears from this investigation, however, that a retained testis is not necessarily imperfect, but may present a retarded, but healthy, degree of development.

2. At whatever position the testis is arrested, and at whatever pre-adolescent age it is examined, the essential elements of the gland, i.e. spermatogonia and undifferentiated cells, are, if not throughout the gland, certainly in many parts, identical in position, structure and relationship with those of scrotal testes of the same age.

This statement corresponds to that of Curling (8) who found the undescended testis healthy but undeveloped.

Despite any reduction in the actual amount of parenchyma, the development and structure of the cells is normal in the retained gland in childhood. Recently Turner (38) has written that full development of the retained testis may be possible up to puberty. Godard (12) believed that the parenchyma of a retained testis was normal, and Félizet and Branca (10) concluded that in a child the lining epithelium of the tubes of undescended testes did not appear very much different from normal.

3. The younger the age at which a retained gland is examined, the more are the normal appearances and characteristics retained.

Rawling (33) has stated recently that in the majority of imperfectly descended testes under ten years of age which he examined, there was no appreciable alteration in the size and consistence of the gland, but in those examined after puberty, it could readily be seen that the organ had not undergone puberty changes. Bland-Sutton (4) has suggested that if a retained testis is functional, it is only for a few years succeeding adolescence. Odiorne and Simmonds (32) state: "It is also true that some testes though undescended, are of normal structure during childhood, but undergo none of the normal changes at puberty."

From the present examination of retained testes it may be stated conclusively that until puberty many of the tubular cells retain their healthy pre-adolescent characteristics, despite any reduction in the amount of parenchyma. After that time degenerative changes may occur which are more marked according to the higher position in which the gland is arrested. It is essential to add therefore that a retained testis, which is placed artificially into the scrotum, will have a much better chance of completing its development if transplanted at an early age.

Turner (38) suggests that full development of a retained testis may be possible until puberty, after which time pathological processes lead to degeneration. "If the testis be transplanted into the scrotum before such

changes occur, there may be a hope that the spermatogenetic function is not entirely lost" (Turner(38)). Thorek(37) advocates the transference of ectopic testes into the scrotum before puberty, before atrophy sets in.

Finally it may be said that the changes in the retained testis are secondary. Such a gland develops normally during the early part of post-natal life, but later, if it has not by that time reached the scrotum, then and then only does it undergo degenerative changes.

4. Certain alterations in the imperfectly descended testes occur:

(*a*) The appearance of fibrous tissue which at first is of a primitive nucleated nature, but later may become fibrosed: this is probably the first change.

(*b*) "Apparent" disappearance of the tubules, probably due to the increase in the stroma causing the tubules to become more widely separated.

(*c*) Persistence of the quiescent state of the nuclei of the spermatogonia at puberty.

(*d*) Disappearance in later years of the more central rows of the tubular cells.

These alterations are recognisable as puberty approaches, and are most marked in those glands which are retained in the abdomen or near the internal abdominal ring. In spite of these changes, however, healthy spermatogonia, undifferentiated cells and cells of Sertoli may be present.

Moore(23) expresses the view that it is known that retained testes are devoid of germinal epithelium, excepting possibly a few spermatogonia. It would appear, however, that so long as even a "few" spermatogonia are present, if the gland be placed into compatible surroundings, they will attempt to mature.

Hanes(13) states that in young pigs, large clear primary sperm cells are seen, but they do not develop further, and no trace of sperm-forming cells can be found in cryptorchid testes in adult pigs.

5. Throughout pre-adolescent life the undifferentiated tubular cells in the retained testis apparently retain their vitality. Many continue to develop into true spermatogonia, whilst others become cells of Sertoli. In both scrotal and retained testes the undifferentiated cells are similar, and at the same period of life (just before puberty) many undergo further specialisation into cells of Sertoli. These are regarded as the nutritive elements of the spermatogenetic cells.

Since the cells of Sertoli persist and maintain their true characteristics in the cryptorchid testis, it seems reasonable to suppose that they are doing their utmost to preserve the healthy condition of the sperm cells, until such time as the testis is placed in a more favourable environment. If, by the time puberty is reached, the testis is still misplaced, then the cells of Sertoli seem to be unable to prevent atrophic changes in the germ cells. It is

remarkable, however, to find that the cells of Sertoli are very resistant to the continuance of a malposition, and they persist even in adult life.

Whitehead (40) and Kingsbury (17) described the essential organs in a hermaphrodite horse and pig respectively. They found that the organ in each case was of testicular origin, and in the tubes were cells of Sertoli. In the essential organ in a human hermaphrodite examined in the course of this research, the tubular cells, with a few exceptions, were typical cells of Sertoli. Moore (24) found that in testicular grafts into castrated males the greater number of cells which persisted were cells of Sertoli. Recently Fukui (11) has shown that in "heat testis" there is a destruction of the germinal cells, leaving the cells of Sertoli, which with excessive heat also undergo degeneration.

Bissonnette (3) describes the majority of tubular cells in the high-flanker testis in cattle as Sertoli cells.

As the cells of Sertoli are not properly developed until just prior to puberty, it seems natural to assume that they are vitally concerned in the maturation of the germinal cells, which also commences at puberty. Since the former cells are resistant to the continuance of the abnormal position of a retained testis, it is surmised that they endeavour to maintain the healthy condition of the spermatogonia in cryptorchid testes, and are ready to nourish the germ cells, should the testis at any time acquire its normal scrotal position.

6. That the retained gland is able to develop in childhood is seen by the increase in size with advancing age; and although in later childhood the tubules appear relatively less numerous than in the scrotal testis of corresponding age, they are collectively in similar numbers, or even more numerous, than at earlier ages, unless the more unfortunate higher degree of retention prevails.

7. The cells of Leydig are apparently not influenced by the abnormal situation of a retained testis.

In the present research they were seen to be in abeyance in the retained glands of earlier ages, and were present and of typical appearance in these glands at puberty and in the adult. Eccles (9) found the interstitial cells in proportionately large numbers in imperfectly descended testes, and Bissonnette (3) describes these cells as being more numerous in the high-flanker testes of cattle. Moore (23) also remarks on the over-abundance of interstitial cells in retained testes, and states that he was able to reproduce a similar condition in testicular grafts placed in castrated males.

By careful comparison with scrotal testes at similar ages, it is concluded that the interstitial cells were no more numerous in the retained than in the normally situated glands. Since they were only present in the abnormally placed glands examined at puberty and in adult life when, it has been seen, the parenchyma may be in smaller amount than normally, the explanation of their apparent exaggeration appears to be that they become more obvious because the tubules are less numerous and more widely separated. It is of

interest to state that a retained testis examined from a human hermaphrodite of thirty-eight years, contained a large number of typical interstitial cells in comparison with the size of the organ and the number of persistent tubes. When compared with a scrotal testis of adult age, these cells collectively did not appear to be excessive as far as could be judged.

8. In no cases of retained testes examined was there anything of an abnormal nature in the structure of the epididymis. The only diversion was that frequently in the retained gland the epididymis and testis were separated by a digital fossa of variable width, but a similar condition was observed also in some scrotal testes, although in smaller percentage.

Bland-Sutton (4), Rawling (33), Turner (38) and Moschcowitz (30) have also drawn attention to the separation of testis and epididymis in imperfectly descended testes. Turner (38) further states that the epididymis, in such an organ, is generally small and ill-developed. In this research, however, the epididymis in the retained testes did not present any abnormal structure.

In conclusion is seems justifiable to advocate the transplantation of the retained testis in all cases during childhood, but especially during the first two or three years, and in those arrested in the lower part of the inguinal canal. Contra-indications for such a procedure are: the persistence of a high abdominal position, when the organ may be removed or left *in situ*; or the infiltration of the testis with secondary growth of a malignant nature, when removal is the only possible treatment.

Since transplantation of a retained testis into the scrotum is practicable, and may induce spermatogenesis, there should be no hesitation in performing the operation, which will incidentally relieve the individual of his "unfortunate infirmity."

ACKNOWLEDGEMENTS

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EXPLANATION OF PLATES I AND II

Plate I

Fig. 1. Testis of a foetus of 7 months. *A*, interstitial cells. *B*, spermatogonia. *C*, undifferentiated cells. × 250

Fig. 2. On left, retained testis of 14 months (A). On right, scrotal testis of 4 months (B). *A*, digital fossa. *B*, epididymis. *C*, vas aberrans. *D*, testis. × 250

Fig. 3. Left, scrotal testis at 11 months (A). × 60. Right, testis retained in inguinal canal, 14 months (B). × 60.
Fig. 4. Retained testis at 2½ years. Situated in higher part of inguinal canal. × 60.
Fig. 5. Retained testis at 5 years. Situated at internal abdominal ring. × 60.

PLATE II

Fig. 6 (A) and (B). Retained testis at 6 years, abdominal situation. *A*, tunica albuginea. *B*, tubules. *C*, digital fossa. *D*, vas aberrans. *E*, testis. *F*, epididymis. 6 B × 35.
Fig. 7. Scrotal testis at 8½ years. × 60.
Fig. 8. Tubules of a testis retained in the inguinal canal, age 13 years. *A*, spermatogonia. *B*, undifferentiated cells. × 400.
Fig. 9. Scrotal testis at 12 years, active spermatogenesis. *A*, spermatogonium with double nucleus. *B*, spermatocytes; as yet there are no spermatids or spermatozoa. × 250.
Fig. 10. Retained testis, abdominal position, age 15 years. No spermatogenesis. *A*, group of interstitial cells. × 60.

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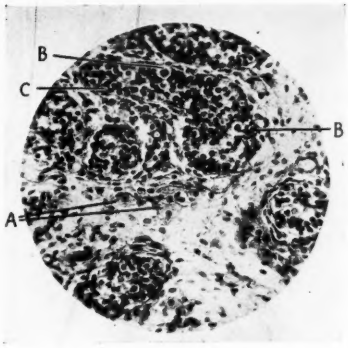


Fig. 1

A Fig. 2 B

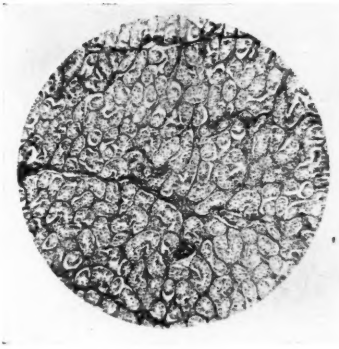
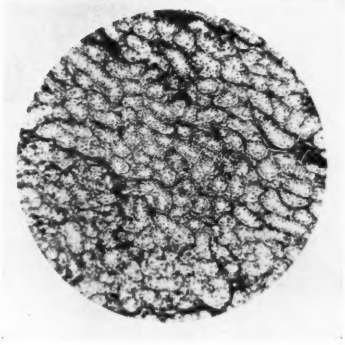


Fig. 3 A



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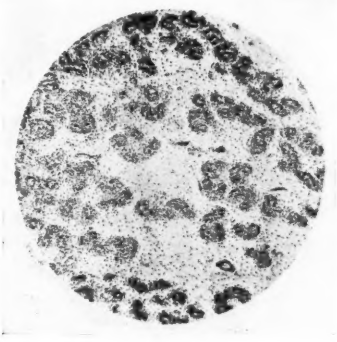

Fig. 4

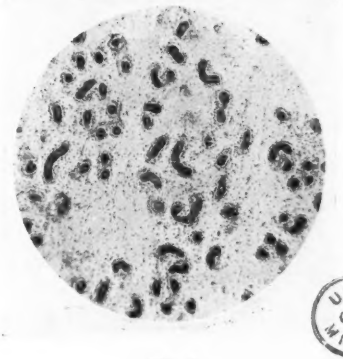

Fig. 5

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A RADIOLOGICAL INVESTIGATION OF THE EPIPHYSES OF THE LONG BONES

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This investigation was undertaken with a view to establish, if possible, with more accuracy than has hitherto been done, the dates of the appearance and fusion of the epiphyses and diaphyses of the long bones.

The radiological method of studying epiphyses has certain evident advantages over the purely anatomical. The examinations are made in the living subject and therefore the age can be indubitably established, as also can the fact that the subject is normal and does not suffer from any of the nutritional or endocrine diseases; moreover, it is possible to examine the epiphyses at various ages in the same individual, but more important still is the facility with which large numbers may be examined and accurate average dates arrived at. The earliest appearance of the epiphyseal centre can be easily detected—when it is no bigger than a pin head—its position can be recorded, and its rate and direction of spread can be watched. The point at which union may be considered to be complete is much more difficult to define. In this investigation it has been assumed to be complete when the epiphyseal space has been filled with bone of equal density to the epiphysis and diaphysis and is therefore invisible on the radiogram. An exception is made of the line-like mark which sometimes persists into adult life—the so-called "epiphyseal scar." It has been pointed out by numerous writers (Frazer, Pryor, Cohn, etc.) that sex has a definite influence on the dates of appearance and union of the epiphyses, the times at which they occur being, as a rule, earlier in females than males. Consequently two lists have been made out for the two sexes. The effect of certain pathological conditions on the epiphyses has been long established and in this series all cases showing any abnormality were excluded. The films were mostly from cases attending the casualty and out-patient department of the Manchester Royal Infirmary for treatment of injury not disease and all radiograms showing signs of such conditions as rickets, scurvy, pseudo-coxalgia and Kohler's disease were discarded.

METHOD ADOPTED

All films—which numbered many thousands—taken in the accident room and out-patient department in the years 1920–1926 inclusive, were sorted out and from them were extracted all radiograms showing joints between the ages of birth and twenty-two. These were then re-sorted into individual

joints and all showing any X-ray evidence of bony abnormality or disease and all films whose ages and sexes were doubtful were thrown out. These collections of films of each joint were finally separated into male and female. An endeavour was made to get a minimum of 100 of each sex of each joint. This number was exceeded in most cases, but was slightly reduced in the case of the knee and hip joints. A special form was devised for each joint and from this the average date of appearance and union of the epiphyses were estimated and also the range of variation (earliest and latest dates). Two forms were used for each joint, one for males and one for females.

The results of these investigations are arranged under separate sections, each dealing with one joint and commencing with the hand and wrist. In Appendix II this arrangement has been altered and there is given the time of appearance and union of the epiphyses for individual bones in tabular form.

UPPER EXTREMITY

The hand and wrist

This section includes the lower end of the radius and ulna, the carpus, metacarpals, and the phalanges. A comparison of the dates given by various authors will be found in the tables in Appendix I.

Frazer described a separate centre for the styloid process of the ulna, but apart from trauma no specimen of this condition was discovered, nor could any evidence be traced of a separate centre for the tubercle of the radius which he mentions as occurring about twenty and joining a few years later.

Phalanges

The epiphyses occur at the proximal end of the phalanges and for practical purposes they seem to appear simultaneously in all three rows. The date of their appearance is relatively constant and was found to be during the third year in males and during the second year in females. No cases were observed of the epiphyses occurring before the third year in males but in all the female cases it was present in the second year. They joined their diaphyses in the male group at the age of nineteen, and in females at seventeen.

Metacarpals

The epiphyses for the metacarpals occur at their distal ends with the exception of that at the first which is at the proximal end. The date of their appearance is the same as those of the phalanges, i.e. males third year, females second year. The epiphysis of the first metacarpal appears generally somewhat later than the others—up to six months later. Dates of joining of the epiphyses were as follows:

	15 years	16 years	17 years	18 years	19 years
	%	%	%	%	%
Males	0	4	15	55	82
Females	32	50	100	—	—

The average age at which the epiphyses of the phalanges and metacarpals join their diaphyses may therefore be stated to be nineteen in males and seventeen in females.

Double epiphyses (proximal and distal) on some or all of the phalanges and metacarpals occurred in several cases. In one of them which was investigated they were apparently hereditary, occurring in the father and two children. These have been described as "pseudo epiphyses" and are not uncommon, sometimes being completely separate and sometimes partially or almost completely fused.

In the present series there were eight cases of double epiphyses, five of them however were confined to the first metacarpal. As far as could be ascertained these cases were present in perfectly normal individuals.

The carpus

All the bones of the carpus normally ossify from a single centre. A double centre for the cuneiform has been described by Pfitzner. It is exceedingly rare and no case of double ossific centres was present in this series. There is a considerable variation in the size and shape of the carpal bones in different individuals. The order of the appearance of the centres was found in males to be as under:

Os magnum. Appears during the first six months after birth.

Unciform. Also appears before six months. The widest variations in these bones are from one to six months.

Cuneiform. End of third year and beginning of fourth. In no case was it present before the beginning of the third year and in only one case was it not present until the fifth year.

Semilunar. End of fourth year or early in the fifth year and the variation limits were between these dates.

Trapezium and trapezoid. Appeared very constantly in the sixth year. There was not more than a six months' variation each way.

Scaphoid. This bone also appeared during the sixth year—see note later.

Pisiform. This is the most variable of the carpal bones, the figures were as follows: 25 per cent. at eleven years, 55 per cent. at twelve years, 80 per cent. at thirteen years, and was present in all cases at fourteen years old. This epiphysis frequently had a "fuzzy" or crumbled appearance which however does not appear to be of any significance.

The figures for female children differ slightly from the above and work out as follows:

Os magnum. Always present at six months.

Unciform. Always present at six months.

Cuneiform. End of second year and beginning of third.

Semilunar. In 50 per cent. of cases was visible during the third year and was invariably present in the fourth year.

Trapezium and trapezoid. End of fourth and beginning of fifth year.

Scaphoid. During fourth year.

Pisiform. Present usually in ninth year, always present in tenth. This carpal bone was in several instances present at the eighth year.

The order of appearance of the trapezium, trapezoid and scaphoid is subject to variation, the two former sometimes appearing before the scaphoid and sometimes after it. It would appear therefore that the centres for the carpus appear from one to two years earlier in females, except the pisiform which may be three or four years earlier. Frazer states: "Ossification of epiphyses appears to start about a year earlier in females in the metacarpus and phalanges and in them the fusion with the shaft is also earlier, in male bones it occurs about eighteen to twenty."

The number of films examined for the above figures were 228 males and 122 females.

The epiphysis for the lower end of the radius appears, according to most authors, at the beginning of the second year. Gray gives "end of second year", Frazer "early in the second year." In a series of cases examined by Cohn radiologically he found this epiphysis to be constantly present at the age of six months. This statement was not confirmed by the present series, in fact in only one case was it found prior to twelve months of age. It was difficult to obtain a sufficient number of films at this age and a series were looked out specially for me from Ancoats Hospital, Salford Royal Infirmary and the Manchester Northern Hospital. All these films confirmed the accepted date and the epiphysis for the lower end of the radius was found in all cases to be first present in the early months of the second year—from fourteen to twenty months. In all cases it was present at the age of two. In males it was not found to have joined the shaft constantly until the twenty-first year, only in 50 per cent. of cases had it joined at twenty. In the female series however it was constantly joined at twenty, that is, about one year sooner.

The lower end of the ulna has a single epiphysis from which the styloid process develops; it appeared very constantly in the male series in the eighth year, but in the female series was very irregular, being present in an isolated instance at the age of four. It joins the shaft at the same time as the radius, namely at twenty-one in males and a year sooner in females.

Sesamoid bones

Two sesamoid bones are found at the head of the first metacarpal and usually one at the head of the second and another at the head of the fifth. These are the commonest in the metacarpus, but nine in all have been described. Their number and situations may vary in the two hands of the same individual and they may ossify from two centres. They become visible on radiograms after the thirteenth year.

The elbow joint

Amongst the many films examined for this investigation there was a great preponderance of epiphyseal injuries at this joint. Epiphyseal separation, displacement and fracture are exceedingly frequent around the elbow joint and a knowledge of the normal therefore becomes most important, particularly as the size and relations of the epiphysis vary with the age.

Up to the ninth year the whole capitellum is anterior to the plane of the centre of the shaft of the humerus, but as ossification extends a full third of the capitellum comes to lie posterior to this plane. The epiphysis of the medial epicondyle of the humerus may appear widely separated from the diaphysis as ossification commences at its medial border and extends towards the diaphysis leaving a large epiphyseal space, and lastly the wedge-shaped epiphyseal space of the olecranon may be easily mistaken for a separation.

Upper end of radius

This is formed from a single epiphysis which appears during the sixth or seventh years. In only a very small percentage of cases was its appearance delayed until the eighth year. It joins the shaft very constantly during the eighteenth or nineteenth year. In the female series the date of its appearance was earlier and usually it was present during the fifth year and invariably present in the sixth. It joins much earlier than in the male and ossification was usually complete in the fourteenth year.

Upper end of ulna

This again is formed from a single ossific centre. The coronoid process develops and ossifies from the shaft, but a separate centre is found for the olecranon. The centre appears near the tip of the olecranon and ossification extends downwards and forwards, leaving a very wedge-shaped epiphyseal space which has its base posteriorly and ossification extends through this space in an antero-posterior direction. It is not uncommon for the olecranon to arise from two centres and occasionally more, in which case one arises in the body of the olecranon and the other in the tip. In the present series 10 per cent. of the cases showed this dual centre which was commoner in male than female children. This epiphysis is not constant in the dates of its appearance and showed a maximum variation of about two years. It was consistently found at the age of eleven in both sexes, but in a few cases was definitely visible at the age of nine. In males it does not join the shaft before nineteen but in females was usually fused at fourteen.

The lower end of the humerus

Ossifies from four centres one for each of the following: the capitellum, the trochlea, the internal condyle and the external condyle. None of these are present at birth.

The capitellum

This is the first epiphysis in the elbow joint to appear and is always visible during the second year of life, i.e. from twelve to eighteen months. It develops from within outwards gradually extending from the olecranon fossa to the external condyle. The earliest date of its appearance in an isolated instance was during the ninth month. At the age of fifteen in males and thirteen in females it fuses with the epiphysis of the trochlea and both join the shaft during the nineteenth year in males but as early as fourteen in females.

The trochlea

This epiphysis appears fairly constantly during the tenth year in both sexes. Its earliest appearance was in the eighth year. For some years it maintains a separate existence but fuses with the capitellum during the fourteenth to fifteenth year in males or even later, but in the thirteenth year in females. It was invariably found to join the capitellum before it joined the shaft, but always joined the shaft shortly (about two years) after it joined the capitellum; it was noticeable, that is, that if these two epiphyses did not join the shaft till late it was also found that they did not join each other till late. The latest date of their union was eighteen years. They join the diaphysis at nineteen in males and at the end of the fourteenth or during the fifteenth year in females.

The internal condyle

The internal condyle was found to be very irregular in the times of its appearance and union with the shaft. Although isolated cases showed a very early appearance—in one instance under five years—there was a definite average time when the majority of cases showed its presence, viz. at the end of the eighth and beginning of the ninth years in males. In females it was usually present at the end of the fifth and beginning of the sixth years, although isolated cases did not show it until the ninth year. It was found to join the shaft somewhere between eighteen and twenty-one in males but much earlier in females, usually at fourteen years. It was in all cases noted that whatever the date of its union it was always the last of the four epiphyses at the lower end to fuse with the shaft (Pl. I, fig. 3).

The external condyle

This epiphysis does not appear to be invariably present. Cohn states that its appearance is the exception rather than the rule. The series examined does not confirm this statement, it was present as a separate epiphysis in 70 per cent. of the cases (Pl. I, fig. 1). In the remaining 30 per cent. it appears to be formed as an extension of the capitellum (Pl. I, fig. 2). When present the date of its appearance is very variable, but usually it occurs at the age of fourteen, it was however found in several cases in the tenth year. It joins the shaft two to three years after it has formed. In some cases its shadow is observed

by the outer margin of the capitellum which renders it difficult to see, and it appears to fuse with the capitellum in some instances. More frequently it maintains a separate existence until it joins the shaft at seventeen or eighteen.

The most noticeable fact in the examination of the elbow joint is the very much earlier date at which ossification is complete in the female subject (Pl. I, fig. 3). It was the rule to find complete fusion of all the epiphyses of the lower end of the humerus in the female at the age of fourteen, whilst in the male this rarely occurred before eighteen or nineteen.

The shoulder joint

A great diversity of opinion appears to exist in the literature, not only as to the time of appearance of the epiphyses of the upper end of the humerus, but also as to their number. Gray's *Anatomy* gives two centres—one for the head and one for the greater tuberosity—but quotes Beclard as stating that there is an additional centre for the lesser tuberosity. Morris' *Anatomy* and Cunningham's *Anatomy* both give three centres. Choyce gives three centres which appear at six and join at twenty-five. Roberts and Kelly also mention an epiphysis for the head, one for the greater tuberosity and one for the lesser tuberosity. Cohn, in a series examined radiologically, came to the conclusion that there was only one epiphysis for the upper extremity and that the two tuberosities were ossified from this centre and that they appeared as downgrowths, very similar to the manner in which the tuberosity of the tibia is ossified. He quotes Poland and Stimson as supporting this view.

At first sight the present series appeared to confirm this view, but a large number of films of patients between birth and five were examined and many were taken specially for the purpose of this investigation. Out of this series three were found which show an unmistakable separate epiphysis for the head and the greater tuberosity (Pl. I, fig. 4). This led to a further investigation and it was then established that about 50 per cent. of the cases had this separate centre, but that in the normal position in which radiograms of the shoulder are taken the shadow of this epiphysis overlaps that of the head and appears very much like a downgrowth from it; careful investigation however and radiograms taken at different angles reveal the fact that it is completely separate. It appears at the end of the second and beginning of the third year and joins the epiphysis for the head at about the fifth year. The remaining 50 per cent. do not reveal the presence of a separate centre, and in these cases the tuberosity apparently ossifies by extension from the head (Pl. I, fig. 5).

In no case of the whole series was there a single instance of a separate epiphysis for the lesser tuberosity, which points to the view therefore that in the ordinary course of events there is no such separate centre. It may occur rarely but if it does it is so rare that it cannot be regarded as the normal method.

To summarise—the head of the humerus ossifies in about 50 per cent. of cases from a single centre for the head and in the remaining 50 per cent.

from two centres, one for the head and one for the greater tuberosity. The centre for the head is either present at birth or appears within the first few months of life. The centre for the greater tuberosity when present becomes visible at the end of the second or beginning of the third year. At about this time the lesser tuberosity is ossified as a downgrowth from the centre for the head and both centres become fused at the end of the fifth year. This composite centre joined the shaft in males in 66 per cent. of cases at the age of twenty and complete union had taken place in all cases at the age of twenty-one. As usual this date was earlier in females and fusion of epiphysis and diaphysis had occurred in all female cases at the age of eighteen.

The clavicle

The clavicle develops from a single primary centre but at the age of about eighteen there appears a small scale-like epiphysis at the sternal end which is stated to join the shaft at twenty-five. Stevenson however showed that it might be delayed until twenty-eight. No sufficient number of these were available to estimate the average date of its appearance and union. It is the last epiphysis in the skeleton to fuse with its diaphysis.

LOWER EXTREMITY

Foot

Phalanges

The phalanges of the foot show considerable variation in size and shape in different individuals. As in the hand the epiphyses occur at their proximal ends and for practical purposes there does not seem to be any difference in the dates of the appearance of the three rows. In the male they become visible at the age of three as small elliptical shadows which rapidly increase in size. In the female series they were present on an average six to twelve months earlier. At the age of seventeen they had fused with the diaphyses in 75 per cent. of the cases and in all cases there was complete union at the age of eighteen. In females this date was as usual earlier and fusion occurred at the end of the fifteenth year.

The metatarsals

The epiphyses for the metatarsals occur at the distal end of the outer four and at the proximal end of the first metatarsal, there is usually no appreciable difference in the date of appearance of the centres though the first metatarsal tends to precede the other four. The actual date of the epiphyseal appearance is the same as that of the phalanges, that is, at the end of the third year in males and about six to twelve months earlier in females. All epiphyses had joined the shaft by eighteen in males and fifteen in females.

The tarsus

All the tarsal bones ossify from a single centre with the exception of the os calcis which has an additional epiphysis for its posterior extremity. Three of these bones have commenced to ossify before birth and as it is not intended to include in this investigation the dates of inter-uterine ossification, they are merely noted as invariably present at birth; they are the os calcis, the astragalus and the cuboid. According to the standard textbooks these bones commence to ossify at the sixth, seventh and ninth months of foetal life respectively. The cuboid's appearance may be delayed for a few weeks after birth.

The first tarsal bone to show a centre of ossification after birth is the external cuneiform, which in the series examined was found to appear during the first twelve months of life in both sexes. This finding is in agreement with that given by most authors (see Appendix I), but is at variance with Cohn, who has published some epiphyseal dates based on X-ray examinations. In his series this centre was not constantly present until half-way through the third year.

The scaphoid

This bone is not very constant in the date of its appearance and was present in some cases at the age of two. It was not constantly present however until a year later. In one instance it was not present at the fourth year—this however must be regarded as an exception. It is not uncommon for this epiphysis to commence from two or more centres, which rapidly coalesce. An apparent abnormality of the scaphoid, in which its outline is irregular, smaller and narrower than normal, was first described by Kohler and subsequently more than a hundred cases have been recorded.

The middle and internal cuneiform

These bones are fairly constant in the date of their appearance and seem to appear about the same time, namely, at the end of the third or beginning of the fourth year. They appear as small shadows and gradually spread until they assume the shape of the adult bone. The date of their appearance was somewhat earlier—up to six months—in female cases examined.

The additional centre for the posterior aspect of the os calcis appears as a small oval centre and rapidly extends into a long narrow scale-like epiphysis from which is modelled the posterior tubercle. The date of the appearance of this epiphysis is very variable—in males from the ninth to the eleventh year and in females from the seventh to the ninth year; the average date was the tenth and eighth year respectively. It was found to join with the rest of the bone during the seventeenth or eighteenth year, but was constantly fused at fifteen in the female series.

The lower end of the fibula

Ossifies from a single epiphysis which by most of the recognised authorities is stated to appear during the second year. It was found in the series under

examination to appear at an earlier date than this, and in all cases it was present at the end of the first twelve months of life. It grows rapidly into a downward projection and is below the level of the corresponding epiphysis of the tibia. It was found to join the shaft at the age of seventeen in 75 per cent. of the male cases and was completely fused in all cases at eighteen. In the female series it had usually fused at fifteen and union was complete in every one at the age of sixteen.

The lower end of the tibia

Here again the time of appearance of the single epiphysis was earlier than the usually accepted date. Its appearance preceded that of the fibula and it was generally to be seen as a small oval shadow at the sixth month of life and was always present before the end of the first year. About the eighth year there commences a downward projection of the ossification to form the internal malleolus. The date of its union with the shaft corresponded to that of the fibula, namely eighteen in males and sixteen in females.

The knee joint

The upper end of the tibia ossifies from a single centre which is apparent in radiograms as a very small circular spot in most cases at birth.

In a few cases it was not visible but was constantly present after the age of one month. It grows very rapidly and at the age of one year has become elliptical and extended to half the width of the diaphysis. At the end of the tenth or during the eleventh year there commences to appear a downgrowth from the anterior portion of the epiphysis which forms the tuberosity of the tibia. This epiphyseal tongue continues to grow until the fourteenth year, its distal extremity is quite widely separated from the tibia forming a wedge-shaped epiphyseal space comparable with that of the olecranon. The lower portion of this epiphysis is consequently the last portion of the tibial epiphysis to unite and remains separate after the actual head of the bone has fused with the shaft. It is not uncommon for the extremity of this tongue to have a separate small centre which, however, ultimately fuses with the main epiphysis or in some cases the whole tongue ossifies from several small separate centres giving it an irregular and segmented appearance. This epiphyseal prolongation of the tibial tuberosity is very irregular and shows wide variation in size and contour in different individuals.

Very varying statements as regards the date of fusion of the epiphysis for the upper end of the tibia are found in the anatomy textbooks. Gray gives the twentieth year and Pringle the twentieth to twenty-fourth year. The series of cases examined were found to be very much more constant than these statments would suggest and fusion was found also to occur at an earlier date. Over 80 per cent. of the cases were united at the age of eighteen and in all cases complete union was established at the nineteenth year. In the female

series a somewhat earlier date was found and here most were joined at sixteen and all at seventeen.

The patella

The centre for the patella is the most irregular in the knee joint. In one instance it was definitely visible at the age of three years. However its appearance is not constant until the fifth year. It occasionally arises from two centres, the second when present being at the lower extremity. Commencing as a small elliptical shadow it grows rapidly and assumes the contour of the normal adult bone. It is difficult to say when this process is complete, but very little if any change appears to occur in its size or outline after the age of sixteen.

The upper end of the fibula

This centre does not show any points of special interest. It was found to be constantly present during the end of the third or beginning of the fourth year. In an isolated instance in a female child it was present at two. Gray gives the date of union of this epiphysis as twenty-five. It was found, however, to be constantly joined at the age of eighteen in males and sixteen in females.

The lower end of the femur

The lower end of the femur is completely formed, including both condyles, from a single centre. This centre was present at birth in the cases examined as a small spherical shadow. At the end of the first year it has become oval and at the age of two commences to take on the shape of the condyles. Its growth presents no points of special interest and its union with the shaft was found to occur at the age of eighteen in males and at sixteen in females. This figure is again some years earlier than that given in the textbooks, which give varying dates from twenty to twenty-five.

HIP JOINT

The upper end of the femur

The upper end of the femur ossifies from three centres, one for the head and one for each trochanter. The epiphysis for the head of the femur was not present in any case at birth, and was invariably present at the age of twelve months. A large number of films under one year was not available, but the average date of appearance seemed to be in the second half of the first year of life. This figure is in agreement with the standard textbooks. The small oval nucleus grows rapidly and at the end of the third year has taken on a hemispherical shape and the form of the adult head. The neck of the femur develops from the diaphysis as an upward growth of the shaft. The neck and shaft were found to unite in males at the age of eighteen, though many were completely fused a year earlier than this. The date of constant union in females was seventeen.

Both the trochanters are developed from the shaft in the same way as the neck but they are both capped by an epiphysis, that for the lesser trochanter being very small and irregular.

The epiphysis for the great trochanter becomes visible as a small irregular shadow which in the earliest cases was present at the fourth year. However, its appearance was not constant until the fifth year. In female children it occurred about one year earlier. The epiphysis for the lesser trochanter is very irregular in its shape and size and in the date of its appearance. It is usually small and scale-like and makes its appearance from the ninth to the eleventh year, though in isolated instances it was present earlier. From the present series it does not appear to be invariably present and a number of films from the age of twelve to fifteen were found to be without it and in which it has apparently never occurred. Table VIII gives the varying ages, according to different authorities, for the union of the three epiphyses at the upper end of the shaft. These were not confirmed by this series of examinations and it was noticed in both sexes that they all joined at the same date. This date varied, but no epiphysis joined either earlier or later than the other two. The average date of union for all epiphyses was eighteen in males and sixteen to seventeen in females.

CONCLUSIONS

Several conclusions, it would appear, are to be drawn from the foregoing investigations. A most striking feature is the difference in the times of appearance, and more particularly in the times of the union of the epiphyses of the two sexes. This difference has been pointed out before but has not been stressed in proportion to its importance, and although the bare fact of the existence of a difference has been quoted by many authors, few actual figures were found in the literature. It is seen that in the case, for instance, of the epiphyses round the elbow joint, there exists a difference of four years between the average dates of union in the two sexes. Parsons and Davies, in a series of epiphyses examined radiographically, also found the dates earlier in females than in males. It is evident, therefore, that any estimation or investigation of these dates, where a sex differentiation has not been made, will give a varying date. If the series contains a preponderance of males, then the date will be a comparatively late one, and if conversely the series predominates in female specimens, it will give a relatively early date of union. It seems possible that this fact may have given rise to some of the very wide ranges of time that have been assigned to various joints, such as "eighteen to twenty-two," and in addition may also account for the wide variations given by authorities for the same epiphyses.

The sex difference in epiphyseal ossification is becoming more recognised. Adair and Scammon have shown that the same relationship holds in intrauterine ossification, and that in the foetus ossification proceeds more rapidly in females even though their weight and dimensions are less than those of

males. The older the individual the more marked is the difference between the two sexes as regards their epiphyses, so that the disparity in the dates of fusion is greater than that of the dates of appearance. As Pryor expresses it: "the bones of the female ossify in advance of the male. This is measured at first by days, then months, then years."

The influence of the endocrines on growth is well known, especially the anterior lobe of the pituitary and the thyroid. Dott has estimated that the average decrease in epiphyseal activity due to anterior lobe pituitary deficiency is 57 per cent., and that athyroidism caused a depression in femoral epiphyseal activity of 81 per cent. He also showed that sexual infantilism followed operations on the pituitary body, and microscopic examination showed atrophic changes in the ovaries and testicles, and that in athyroidism the generative glands and organs present both the gross and histological appearances of infantilism. In hyperthyroidism the generative organs share the general acceleration of maturity without deviation from the normal, beyond their more rapid development. The same author is of the opinion that the action of the anterior lobe of the pituitary and of the thyroid are very similar on cell activity, but the pituitary has a more selective action on embryonic tissue as represented by epiphyseal cartilage. Total excision of the pituitary was followed by acute thyroid hyperplasia.

There is no doubt that the sex glands are capable of affecting the thyroid, and their connection is witnessed also by the physiological enlargement of the thyroid at puberty, marriage and pregnancy (Langdon Brown). Dixon in 1923 showed that injection of ovarian extract stimulated the anterior lobe of the pituitary. It has been shown that castration delays ossification even if it does not inhibit it. Puberty in both sexes has a very pronounced effect on ossification, and announces one of the most active phases of the process. As puberty and sexual maturity occur earlier in the female, and as ossification is associated with both these events, there is no anomaly in the earlier ossific changes in the female. Lipschutz quotes several at an abnormally early age. All his cases were associated with endocrine disturbance. The author has seen two cases of sexual precocity as evidenced by enlargement of the breast, menstruation, the growth of pubic and axillary hair, etc., one at the age of twelve and the other at fourteen. In one of them menstruation commenced at the age of eleven and the other signs preceded it. This case had hyperthyroidism at the age of two which was treated radiologically and presented some very interesting endocrine disturbances. The relevant feature, however, here is that, associated with the early sexual maturity, was early epiphyseal union. At the age of twelve most of the epiphyses were joined and the others were almost fused. The other case was less marked, showed some sexual precocity, and an enlarged pituitary fossa. Here also epiphyseal growth was ahead of the normal.

These brief facts all confirm the close association of the sex glands and epiphyseal growth, hyperactivity accelerating fusion and under-activity

retarding it, as is evidenced by the increased size of eunuchs. Prof. Elliot Smith has suggested that dystrophia adiposa genitalis delayed the epiphyseal union of the bones of Tutankhamen. It is not clear whether this interaction between the sex glands and the rate of epiphyseal growth is a direct one, or whether it is through the medium of other glands such as the thyroid and pituitary. Eunuchs and persons with under-activity of sex glands from one cause or another, although their epiphyseal union may be delayed, do not necessarily show evidence of other endocrine disturbances. On the other hand, most of the reported cases of sexual precocity with epiphyseal changes showed abnormality of some or other of the ductless glands, and our own cases certainly did. Whatever the mechanism the fact cannot be denied, and it seems probable that there is a very delicate and balanced state of endocrine equilibrium, which, once upset at any point, may produce certain definite results although the actual point of disturbance is not the same one in each case but an associated one.

On the whole the present series shows earlier dates of appearance and earlier dates of union than are usually accepted. The early date of appearance is perhaps to be expected from the method adopted, as the very earliest commencement of ossification is demonstrable on a radiogram, but it is difficult to see why the more marked earlier date of fusion should be so pronounced. It must be pointed out that all figures in this investigation were worked out from films taken in hospital in a large industrial area and it is proper to assume therefore that the vast majority of cases were engaged in some form of manual or physical labour—a fact which applies in both sexes—and it is possible that this fact in some degree accounts for the earlier date of fusion of epiphysis and diaphysis.

Schinz, Baensch and Friedl have published work showing that the date of epiphyseal union is affected by social position. They give comparative figures of the date of fusion in the children of peasants, artisans and well-to-do people of the same age.

Variations of the normal in the epiphyses are far from rare as shown in this series, the chief ones being irregular ossification, double or multiple centres of ossification, "pseudo-epiphyses" (very completely discussed by Wakeley), failure of the process of ossification to extend, and lastly, failure of union to occur at the normal date. Certain accessory bones, particularly in the hand and foot, are quite common and differential diagnosis between them and true fractures is of great importance, particularly when the question of compensation for injury arises.

That certain recognised epiphyseal centres do not appear to be invariably present seems to be a conclusion from the investigation carried out. This remark applies particularly to the external epicondyle and the lesser and greater tuberosities of the humerus.

SUMMARY

1. The radiological method of examining epiphyses presents certain advantages.

2. An estimation of the age of appearance and fusion of the epiphyses of the long bones was made from 1000 radiograms of children of both sexes.

3. All epiphyses appear up to six months earlier and fuse up to five years earlier in the female.

4. Dates of union estimated by the radiological method are earlier than those generally accepted.

5. Abnormal epiphyses and accessory bones are not uncommon.

6. Sex glands are closely associated in some way with ossification.

EXPLANATION OF PLATE I

Fig. 1. Normal elbow, male, aet. 14. All four epiphyses for the lower end of the humerus are present. The external condyle has a separate centre of ossification. Compare with Fig. 2.

Fig. 2. Normal elbow, female, aet. 13. Shows external condyle to be ossifying as an extension of the nucleus for the capitellum. This occurred in 30 % of cases.

Fig. 3. Normal elbow, female, aet. 14. Showing fusion of all the epiphyses except the int. condyle which is always the last to join. In most cases it also is joined at this age in the female.

Fig. 4. Normal shoulder, male, aet. 2½. Showing separate centre for the greater tuberosity.

Fig. 5. Normal shoulder, female, aet. 2½. Showing greater tuberosity apparently developing as a downgrowth of the epiphysis for the head, i.e. the upper end of the humerus, ossifying from a single centre.

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Fig. 1

Fig. 2

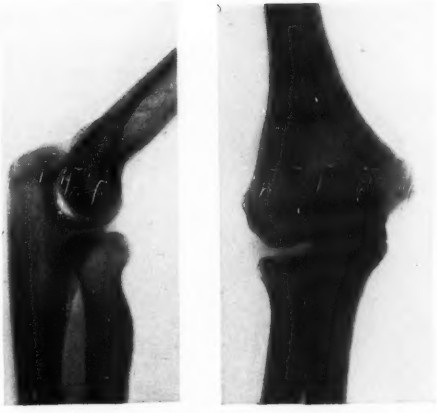

Fig. 3

Fig. 4

Fig. 5

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APPENDIX I

Table I. *Times of appearance and union of epiphyses for lower end of the radius and ulna from various authors*

	Lower epiphysis radius		Lower epiphysis ulna	
Author	Appears	Ossifies	Appears	Ossifies
Gray	End of 2nd year	18–19	4	20
Morris	2	20	6	20
Scudder	About 2	19–20	—	—
Poland	End of 2nd year	19–23	4–5	18–20
Cohn	6 months	20–21	6–7	20–21
Cunningham	2	21	6	21
Frazer	M. 2 F. 1½	22 —	M. 6–7 F. 5–6	20 —
Paterson	*M. 1–1½* *F. 1*	*M. 21* *F. 19*	*M. 8* *F.*	*M. 21* *F. 19*

Table II. *Times of appearance of centres of ossification of the bones of the carpus according to various authors*

Author	Scaphoid	Semi-lunar	Cunei-form	Pisi-form	Trape-zoid	Trape-zium	Unci-form	Os magnum
Gray	6	5	3	12	8	5	1	1
Cunningham	5	5	3	10	7	5	1	1
Frazer	5–6	4	3	11	7	5–6	2	1
Cohn	4–5	4	2–3	10–13	5–6	5–6	6 mos.	6 mos.
Poland	5	4½	2	13	4½	4½	1	8 mos.
Paterson	*M. –6* *F. –4*	*M. 4–5* *F. 3–4*	*M. 3–4* *F. 2–3*	*M. 13–14* *F. 9–10*	*M. –6* *F. –5*	*M. –6* *F. –5*	*M. 6 mos.* *F. earlier*	*M. 6 mos.* *F. earlier*

Table III. *Time of appearance of centres in the lower end of the humerus according to various authors*

Author	Capitellum	Int. condyle	Ext. condyle	Trochlea	Complete fusion
Gray	End of 2nd year	5th year	13–16	12	—
Cunningham	End of 2nd year	5	12	12	16–17
Frazer	2–3	5–8	12	11	17
Spalteholz	1–3	5–9	11–18	8–16	17
Morris	3	5	10	14	17
Piersol	6 mos.	5	10	14	—
Quain	3	5	11 or 12	13–14	16–17
Buchanan	3	5	12	14	17
Roberts and Kelly	1	10–12	10–12	10–12	20–22
Ashurst	6 mos.	6	12 not constant	11	15
Paterson	*1–1½*	*M. 8–9* *F. 5–6*	*14 (70 %)*	*10*	*M. 18–21* *F. 14–15*

Table IV. *Times of appearance and fusion of centres for the upper end of the humerus according to various authors*

Author	Head	Greater tuberosity	Lesser tuberosity	Union
Gray	1	3	3	20
Cunningham	6 mos.	2–3	3–5	25
Piersol	6 mos.	3	After 3	20–21
Cohn	1	Not present	Not present	20–22
Frazer	1	3	4	20–25
Paterson	*Under 6 mos.*	*M. 3* *F. 2*	*Not present*	*M. 21* *F. 18*

Table V. *Times of appearance of centres of ossification for the bones of the tarsus according to various authors*

Author	Os calcis	Astragalus	Cuboid	Scaphoid	Ext. cuneiform	Int. cuneiform	Mid-cuneiform
Gray	6th foetal month	7th foetal month	Birth	4	1	3	4
Cunningham	6th foetal month	8th foetal month	Birth	4	1	2	3
Frazer	6th foetal month	6th foetal month	Birth	5	1–2	2–3	3–4
Piersol	6th foetal month	7th foetal month	Birth	4–5	1	3	4
Cohn	Present at birth	Present at birth	Present at birth	3½–4	3½	3½	3½–4
Morris	6th foetal month	7th foetal month	Birth	4	1	3	4
Paterson	*Present at birth*	*Present at birth*	*Birth or soon after*	*3*	*1*	*M. 4* *F. 3*	*M. 4* *F. 3*

Table VI. *Epiphyseal centres for lower end of tibia and fibula according to various authors*

Author	Lower end tibia		Lower end fibula	
	Appears	Unites	Appears	Unites
Gray	2	18	2	20
Cunningham	2	18	2	18–20
Frazer	2	After puberty	2	21
Piersol	1½	18	2	18–19
Morris	2	18	2	20
Cohn	5 mos.	18	13 mos.	18
Paterson	*6–12 mos.*	*M. 18* *F. 16*	*12 mos.*	*M. 18* *F. 16*

Table VII. *Epiphyses around the knee joint. Dates of appearance and fusion according to various authors*

Author	Upper end of tibia		Upper end of fibula		Lower end of femur		Patella
	Appears	Unites	Appears	Unites	Appears	Unites	Appears
Gray	Shortly after birth	20	4	25	Birth	20	3
Cunningham	Birth	21	2	18–20	Birth	21	3
Frazer	Birth	20–24	3	20–24	Just after birth	21–24	3
Piersol	Birth	19–20	4–5	20	Birth	20	2–5
Morris	Birth	21–25	4–5	22	Birth	20	3
Cohn	Birth	19	5	18	Birth	19	5 irreg.
Paterson	*Birth or soon after*	*M. 18–19* *F. 16–17*	*M. 4* *F. 3*	*M. 18* *F. 16*	*Birth*	*M. 18* *F. 16–17*	— *5*

Table VIII. *Times of appearance and union of epiphyses for the upper end of the femur according to various authors*

Author	Head		Great trochanter		Lesser trochanter	
	Appears	Unites	Appears	Unites	Appears	Unites
Gray	1	18	4	18	13–14	18
Cunningham	Under 12 mos.	18–20	2–3	18–29	12–13	18
Frazer	1	18	3	18	12–13	18
Piersol	1	18	3	19	8–14	19
Morris	1	19	4	18	11	17
Cohn	1	15–16	5	15–16	9–11	15–16
Paterson	*M. ½–1* *F. 6 mos.*	*M. 18* *F. 17*	*M. 5* *F. 4*	*M. 18* *F. 16–17*	— *9–11* irreg.	*M. 18* *F. 16–17*

APPENDIX II

Table of epiphyseal dates

Bone	Epiphysis	Date of the appearance of epiphysis		Date of their union to each other		Date of their union to the shaft	
		Male	Female	Male	Female	Male	Female
Clavicle	Sternal end	About 18		—	—	About 20	
Humerus	Head	Birth or shortly after		6	5	21	18
	Gt tuberosity	3	2	—	—	—	—
	Capitellum	1–1½	—	—	—	—	—
	Trochlea	10	10	15	13	19	14–15
	Int. condyle	8–9	5–6	—	—	18–21	14–15
	Ext. condyle 70 %	About 14		—	—	17–18	14–15
Radius	Upper end	6–7	5–6	—	—	18–19	14–15
	Lower end	1–1½	1	—	—	21	19–20
Ulna	Olecranon	11	11	—	—	18–19	14–15
	Lower end	8	Irreg.	—	—	21	19–20
Carpus	Os magnum	6 mos.	6 mos. or before	—	—	—	—
	Unciform	6 mos.	6 mos. or before	—	—	—	—
	Cuneiform	3–4	2–3	—	—	—	—
	Semilunar	4–5	3–4	—	—	—	—
	Trapezium and trapezoid	6	4–5	—	—	—	—
	Scaphoid	6	4	—	—	—	—
	Pisiform	13–14	9–10	—	—	—	—
Metacarpals	1	2½	1½	—	—	19	17
	2, 3, 4 and 5	3	2	—	—	19	17
Phalanges	3 rows	3	2	—	—	19	17
Femur	Head	½–1	0–½	—	—	18	17
	Gt trochanter	5	4	—	—	18	16–17
	Lesser trochanter (irreg.)	9–11	9–11	—	—	18	16–17
	Lower end	Present at birth		—	—	18	16–17
Patella	—	About 5		—	—	—	—
Tibia	Upper end	Birth or soon after		—	—	18–19	16–17
	Lower end	6 mos. to 1 yr		—	—	18	16
Fibula	Upper end	3–4	3	—	—	18	16
	Lower end	1	1	—	—	18	16
Tarsus	Os calcis	Present at birth		—	—	—	—
	Secondary centre	9–11	7–9	—	—	17–18	15
Tarsus	Astragalus	Present at birth		—	—	—	—
	Cuboid	Present at birth or soon after		—	—	—	—
	Ext. cuneiform	During first year		—	—	—	—
	Scaphoid	During third year		—	—	—	—
	Mid. cuneiform	4	3	—	—	—	—
	Int. cuneiform	4	3	—	—	—	—
Metatarsals	2–3, 4, 5	3	2	—	—	18	15
	1	Few mos. earlier		—	—	—	—
Phalanges	All three rows	3	2	—	—	18	15

A DIVERTICULUM OF THE APPENDIX

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The specimen which is described here is a vermiform appendix with a diverticulum. It is from a male child aged eight years. The appendix is 10 cm. ($3\frac{7}{8}$ inches) long. It is of regular tubular form, is coiled at its apical end, and is spirally twisted on its long axis. The mesenteriole reaches to the apex of the appendix and contains the appendicular artery near its free edge. The diverticulum (fig. 1) is on the anti-mesenteric border, 19 mm. ($\frac{3}{4}$ of an inch) from the apex. It is conical in form and is 6 mm. ($\frac{1}{4}$ of an inch) in its free length; at its base it is the full size of the appendix but it tapers uniformly to its pointed apex. It receives two small twigs from the appendicular artery. The surgeon from whom I received the specimen had not noted its position in the body; but the upper end of the mesenteriole would be best placed and in the most usual position of a posterior mesentery if the coiled apex is directed to the right. The diverticulum is then directed downwards and backwards towards the posterior abdominal wall. It was determined by section that the cavity of the diverticulum is freely open into that of the appendix, there being no constriction at the mouth; and, like the distal half of the appendix, it was full of a dark brown faecal mass. The wall of the proximal part of the appendix is normal in its structure apart from a slight inflammatory reaction of its mucous membrane. The wall of the distal part of the appendix is thinner than usual, but the several proper layers are readily recognised; the inflammatory reaction is greater. The wall of the diverticulum is a little thicker than the wall of the distal part of the appendix but is similar to it in structure and presents the same signs of inflammation; the mucous layer contains Lieberkuhn's glands and a little lymphoid tissue; and the submucous layer, the muscular layers, and the serous covering are regularly disposed over the whole diverticulum, except at its apex where the subserous layer is thickened.

Fig. 1

The interest of this specimen lies in the attempt to decide the nature of the diverticulum. There are several possibilities but, from the structure of its wall, it is not a false diverticulum. False diverticula of the appendix have

been recorded (Ribbert, Edel, Mertens), and I have had them reported to me by surgeons. They are apparently more common in old people, are frequently multiple, and are similar in their structural features to false diverticula of other parts of the intestine.

(*a*) The diverticulum may represent a persistence of the normally transitory structure at the apex of the early caecum. This structure, which disappears in the eighth week, is usually solid but sometimes does contain a lumen lined with epithelium. Its position, however, in all the descriptions I have seen of it, is at the apex of the caecal anlage.

(*b*) It may be similar to the diverticula which are produced by the abnormal persistence and enlargement of the cyst-like pouchings of the epithelial wall that are formed in the restoration and expansion of the lumen of the developing gut. These diverticula are usually submuscular, but some of them are protrusions which closely resemble a Meckel's diverticulum and in their walls the whole thickness of the gut wall is found. Such diverticula have been recorded in all parts of the abdominal alimentary tract—in the stomach, duodenum, jejunum, ileum, caecum, and colon, and are often described as abnormally placed Meckel's diverticula—and at least once, by Hedinger, in the appendix. In Hedinger's specimen the proximal part of the appendix was normal but in the distal part there were multiple diverticula; some of the diverticula reached only to the muscle coat but some of them formed protrusions on the surface and included all the coats of the appendix in their wall.

(*c*) It may be a "traction" diverticulum, due to an adhesion of the appendix to the plica vascularis. This fold is sometimes well developed in the young, and, as it is described by Lockwood, is that part of the mesorchium which is reflected over the spermatic vessels and in which there are unstriped muscle fibres. It passes below into the peritoneum covering the psoas muscle, while above, on the right side, according to Wrisberg, it ends on the ileum, the mesentery, the caecum, or the appendix. The appendiculo-ovarian ligament of the female, which, when it is admitted to exist, is usually said also to contain muscle fibres, would be a corresponding structure. The gut attachment of the upper end of the plica vascularis must be a secondary one, but that such an attachment may occur to the appendix is shown by the case described by Rolleston; and as "traction" diverticula are recognised in other parts of the gut it is possible that such might be induced in the appendix by the plica vascularis. There was no such attachment in this specimen, but the apex pointed, I think, towards the plica and the thickening of the subserous coat there suggests that it was originally continued into a cord. It is of interest however in this connection also to speculate whether some of the diverticula of the terminal ileum which have been described as Meckel's diverticula may not be "traction" diverticula; namely, those conical diverticula four, six, or eight inches from the ileo-caecal junction which have prolonged from their apex a fibrous cord that is attached to the anterior abdominal wall at the deep abdominal ring. (Cases are described by Mitchell.)

(*d*) The diverticulum may be, and I think probably is, a Meckel's diverticulum. There is no impossibility in this interpretation. It only implies that the caecal pouch is formed very close to the vitello-intestinal junction; and I have already reported to the Society (*Proc. Anat. Soc.* May, 1921) a specimen in which a persistent vitelline duct, patent in its whole length and prolapsed at its distal end through the umbilicus to which its margin was fixed, was attached to the anti-mesenteric border of the distal part of the appendix.

The ultimate problem is, of course, to determine the factors which define the position of the caecal anlage on the intestinal loop or, in terms of development, which determine the junction between a rapidly lengthening part of the gut—the small intestine—and a much more slowly growing part—the proximal part of the large intestine. The junction itself is certainly very variable in its adult form among Mammals; it is probably variable in its position in the human subject. I should be very grateful if those who meet with cases of Meckel's diverticula would send me the following data; the length of the small intestine to the duodeno-jejunal junction on the proximal side of the diverticulum, and on the distal side the length of the ileum and the length of the large gut to the splenic flexure.

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THE THYROID ARTERIES CONSIDERED IN RELATION TO THEIR SURGICAL IMPORTANCE[1]

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This paper embodies the result of an investigation of the arterial supply of the thyroid gland in normal and goitrous subjects, undertaken because efforts to find a precise and authoritative record of the position, condition and distribution of the thyroid arteries were unsuccessful.

The blood supply of the normal thyroid gland is a very rich one. C. H. Mayo estimates it as relatively 3·4 times as great as that of the brain while Tschuewsky calculates that the gland is nearly six times as vascular as the kidney, and that in the dog the entire amount of blood in the body flows through the thyroid sixteen times per day. This abundant blood supply is much increased in some goitres, notably the purring and throbbing variety seen in certain cases of primary Graves' disease and designated by Theodore Kocher "struma vasculosa."

Because of this relatively great blood supply it is not surprising that for many years efforts have been made to treat thyroid enlargements by reducing the blood flow into the gland, and early in the seventeenth century goitre in horses is said to have been treated by ligation of the superior thyroid arteries. In 1813 the first thyroid ligation in man was performed. Sir William Blizard at the London Hospital tied one superior artery but subsequently lost his patient from secondary haemorrhage. The following year however a successful attempt was made by Walther of Landshut who ligated both upper arteries in a young man suffering from dyspnoea produced by a goitre.

Luigi Porta in 1845 seems to have been the first to suggest tying an inferior artery as well as both the superior vessels.

Towards the close of the nineteenth century ligations were commonly practised, but with the advent of aseptic surgery they were almost entirely replaced by thyroidectomies of varying extent, except in toxic cases in which the operation had the support of Kocher who was however in favour of ligating only three of the four main arteries.

Within recent times ligation has been quite abandoned except for toxic goitre for some cases of which it has been extensively practised by Sir James Berry in England and by Crile in America, and to-day, owing to the introduction of the pre-operative iodine treatment of Graves' disease, ligations as

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separate operations for toxic goitre are much less often performed than they were a few years ago. Some surgeons however still resort to ligations for certain very vascular and highly toxic cases, and when, as sometimes occurs in these patients, the thyroid enlargement is very slight, these workers believe that quadruple stage ligations offer the safest and most effective means of treatment[1].

Kocher did not consider it permissible to tie all four arteries because on the one occasion on which he performed quadruple ligation his patient subsequently developed tetany. This was probably due to the fact that he tied the inferior thyroids close to or within the capsule of the gland and so cut off the blood supply to the parathyroids. In numerous cases treated by quadruple ligation by De Quervain, John Rogers of New York and myself, neither tetany nor myxoedema have been noticed, but these cases have been treated by trunk ligation which permits the formation of a collateral blood supply to the thyroid and parathyroids.

Crotti points out that if the four main thyroid arteries are injected, not only does the whole gland become injected but also the adjacent parts of the trachea and oesophagus. This is an important fact since it demonstrates the free anastomosis existing between the branches of the main thyroid vessels and indicates that after ligation of the four main arteries the gland can still receive blood from its collateral circulation.

When present, Neubauer's artery, the thyroidea ima[2], must form an important affluent to the collateral circulation formed as a result of ligating the main arteries.

Opinions differ as to relative size of the thyroid arteries. Although from the point of view of comparative anatomy it might be thought that the superior would be a larger and more important vessel than the inferior, Sir James Berry in 1901 stated that this was not so, that the superior thyroid vessels are usually much smaller than the inferior and that ligature of those vessels alone did not cut off enough of the blood supply to the thyroid to be of any real value. However, Sir James strongly advocated preliminary ligation before resection in very toxic cases, and because of the difficulties and dangers associated with ligation of the deeply placed inferior arteries, chose the superior vessels.

A series of dissections was undertaken therefore to ascertain: (1) which are the larger thyroid vessels, (2) what is their precise anatomical position, (3) whether, in the event of Sir James Berry's contention being verified, it was possible to expose the inferior thyroid artery by a route which would enable its ligation to be more safely practised.

The examination of these dissections of the thyroid apparatus in the

[1] Lambert Rogers, "The Treatment of Graves' Disease by Ligation," *Brit. Med. Journ.* Mar. 27, 1926, p. 561.

[2] In this paper I have not dealt at length with this vessel because when present it is as a rule very small relatively to the upper and lower arteries.

cadaver, of the dissections, or drawings made from them, of others, and of the vessels of goitrous subjects during the exposure of the vessels at operation has resulted in the following conclusions.

(*a*) THE SUPERIOR THYROID ARTERY

This vessel is apparently the primitive artery to the gland and is a constant vessel. I have not once found it absent[1].

Its downward curving course in both man and animals indicates an early vascularisation of the caudally growing thyroid anlage.

The constancy of the vessel in man is paralleled by many animals in some

Fig. 1. Modified from Sisson's *Veterinary Anatomy*. 9=superior thyroid artery arising from 7, thyro-laryngeal branch of carotid. The downward bend of the superior thyroid artery is shown.

of which an inferior artery is altogether absent while in others it is only occasionally present. Thus, in the ox the superior thyroid is represented by the arteria thyroidea cranialis from the thyrolaryngeal branch of the carotid while an inferior (accessory) artery is only exceptionally present (fig. 1). In the horse, as in the ox, both vessels arise from the carotid, but whereas the downwardly curving superior vessel corresponding to the upper artery in man is constant, the lower (accessory) artery is only occasionally present. Absence of one inferior artery is occasionally met with in man, but the inferior artery generally becomes the larger of the thyroid arteries, and, as it is believed will be shown here, the more important vessel to ligate. This development of the inferior artery beyond that of the upper and primitive vessel may be compared with the development of the femoral artery at the expense of the sciatic, the primitive artery of the lower limb.

[1] Although Quain (*Anatomy of the Arteries*, p. 171) states that in some cases it may be said to be wanting, not once in his many excellent sketches does he depict a complete absence of this artery as he does of the inferior.

Dissection has shown that the superior artery, after its origin from the external carotid just below the great cornu of the hyoid and beneath the anterior border of the sterno-mastoid, forms a loop lying on the inferior constrictor and the external laryngeal nerve. It turns downwards giving off its hyoid, superior laryngeal and sterno-mastoid branches and after a very short course bifurcates at one of three points, namely (1) in the carotid triangle, (2) immediately behind the upper belly of the omo-hyoid, or (3) further forward in the muscular triangle. The larger of the two divisions runs downwards, forwards and towards the mid-line behind the sterno-thyroid muscle to the upper pole of the gland where it breaks up into branches, a large one of which runs down the back of the gland. The other branch is superficial and runs forwards in the groove between the sterno-thyroid and thyro-hyoid muscles giving branches to these muscles and to the sterno-hyoid. The branch to this muscle[1] is the largest and most constant of these muscular twigs and enters the muscle posteriorly at the junction of its upper and middle thirds where it may need a clip when dividing the muscle in the course of a goitre operation necessitating division of the infra-hyoid muscles. After giving off its muscular branches the superficial division continues downwards, gives off the crico-thyroid branch and breaks up into twigs for the isthmus and inner sides of the lateral lobe, supplying also Lalouette's lobe when this is present. When this pyramidal lobe is well developed the superficial branch of the artery is well developed also and is the main arterial supply to this part of the thyroid.

Anomalies. The only anomaly I have observed is a common origin for this vessel and the lingual[2]. A stem common to these two vessels and the facial also has been described while the superior thyroid is said very rarely to spring from the common carotid. The superior laryngeal and sterno-mastoid branches are described as occasionally arising independently from the external carotid[3].

Ligation of the superior thyroid artery. Either trunk or polar ligation may be practised, the polar method including a small part of the upper extremity of the lateral lobe in the ligature which occludes not only the artery but also its accompanying veins and lymphatics.

The artery is exposed through a transverse incision or one slightly oblique in a downward and inward direction, at a level just below the upper border of the thyroid cartilage.

If the trunk is to be tied the vessel is exposed between the anterior edge of the sterno-mastoid and the omo-hyoid which is pulled forwards and inwards.

[1] Lambert Rogers, "The Sterno-Hyoid Artery," *Lancet*, Feb. 19, 1921, p. 378.

[2] I saw recently exposed at operation a cystadenomatous goitre affecting the right lobe of the thyroid of a child aged 12. The isthmus and left lobe were absent, the whole mass of the goitrous thyroid lying to the right of the trachea. The blood supply was right-sided only and both upper and lower arteries were much enlarged.

[3] C. M. West has recorded (*Journ. Anat.* April 1923, p. 272) a case of undescended thyroid which received its blood supply almost entirely from the left lingual artery which divided into two branches, one for each side of the gland. A small superior thyroid artery was present also.

The loop of the artery is sought lying on the inferior constrictor and below the superior laryngeal nerve, but as Kocher has pointed out it may be necessary to free the external carotid and expose the artery at its origin.

In performing polar ligation, the upper pole is first palpated and the omo-hyoid and sterno-hyoid are separated just above it, the sterno-thyroid fibres are split and the neuro-vascular bundle is identified as it enters the upper pole.

Whichever method is practised, care should be taken to include in the ligature the posterior branch of the artery. This branch sometimes arises high up and passes down the back of the lobe. Severing between ligatures what appears to be the main vessel will enable the surgeon to see whether the posterior branch has been included or not.

(*b*) THE INFERIOR THYROID ARTERY

In the older works on anatomy, the transversalis colli and suprascapular arteries were regarded as branches of the inferior thyroid, but it is now customary to regard these as two of three divisions of the thyroid axis of which the inferior thyroid forms the third.

The following description is based upon a number of special dissections which I have made of this vessel.

Arising from the axis at the inner border of the scalenus anticus muscle, the inferior thyroid artery passes upwards resting upon the longus colli muscle. From the highest point of its ascent it gives off the ascending cervical branch and then at the level of Chassaignac's tubercle turns inwards still lying upon the longus colli and passing behind the carotid sheath and usually also the middle cervical ganglion of the sympathetic trunk, enters the hilus of the lateral lobe of the thyroid, either as a single trunk or as a series of diverging branches. This point of entrance corresponds to a point at, or a little above, the junction of the upper two-thirds with the lower third of the outer border of the lobe, but is on its posterior surface.

The important relationship which the vessel bears to the recurrent laryngeal branch of the vagus is a variable one. The nerve may pass either in front of or behind the vessel, in two dissections the nerve on the right side was in front of the artery while that on the left was behind it; both vessels may pass either in front of or behind the corresponding nerve, or the nerve on either or both sides may be related either anteriorly or posteriorly to the terminal branches of the artery. Finally in some cases the nerve has been found threading through these branches on one or both sides, thus passing behind one or several and in front of the remainder (fig. 2).

The oesophageal, tracheal, inferior laryngeal, and muscular branches of this artery are all small vessels; the ascending cervical is much the largest branch, and in performing ligation care must be taken to see that this branch is not mistaken for the inferior thyroid itself.

Anomalies. The only anomalies I have found are an occasional absence of the artery on one side, and in one dissection a normal artery on the right side with a double one on the left (fig. 3). Both trunks of the double artery sprang from a short common stem from the thyroid axis, and each entered the hilus separately[1]. Quain states that the inferior artery may arise from the common carotid, vertebral or subclavian as an independent trunk.

The importance of the lower artery depends upon the fact that it is the artery to the hilus of the gland. Sir James Berry drew attention to this in 1901 and G. C. Williamson has recently shown by histological methods that the parenchymatous supply of each thyroid lobe is derived from the four or five terminal branches of the inferior thyroid artery entering the lobe at the hilus, and that there is only an inconstant connection between the upper and lower vessels, while the ramifications of the superior artery on the other hand appear to be mainly superficial and septal.

Secondly, my dissections have shown that the inferior is usually the larger artery to the normal thyroid, and as De Quervain points out, and my experience has confirmed, this vessel enlarges still more when the gland is goitrous, since the lobar enlargement is mostly towards the lower part of the gland.

It follows that since the inferior artery is generally larger than the superior, and because, entering the hilus, the inferior thyroid artery forms the chief functional blood supply to the gland, it is desirable to ligate this vessel in preference to the upper artery. The great disadvantage however is the practical difficulty of the artery being so deeply placed, and of its tendency to be obscured by overriding of the lateral lobe of the thyroid if the goitre is a large one. This difficulty is most obvious when attempts are made to ligate the inferior thyroid artery through an incision along the anterior border of the lower part of the sterno-mastoid, the route described in textbooks of operative surgery.

It is desirable to ligate the artery near its origin because here the operation is carried out as far from the thyroid as possible and at the same time well away from the recurrent laryngeal nerve, and because here also the main trunk of the artery is tied, and hence owing to the free extra-capsular anastomosis, there is little danger of interfering with the development of a collateral circulation to the parathyroids. It may be objected that at a point near its origin the artery is in relation to the sympathetic and its middle cervical ganglion, either of which may be injured, but injury to the cervical sympathetic is not only of no practical importance, but deliberate avulsion of any of its fibres which appear in the wound is advocated by those who believe in the Jonnesco operation for Graves' disease.

To expose the vessel near the thyroid axis, incisions have been used either

[1] Quain (Plate XXIII, fig. 11, Arteries) has noted an example of this duplication of the inferior artery, in which one vessel passed in front of, the other behind the common carotid. In the instance I have noted both vessels passed behind the carotid.

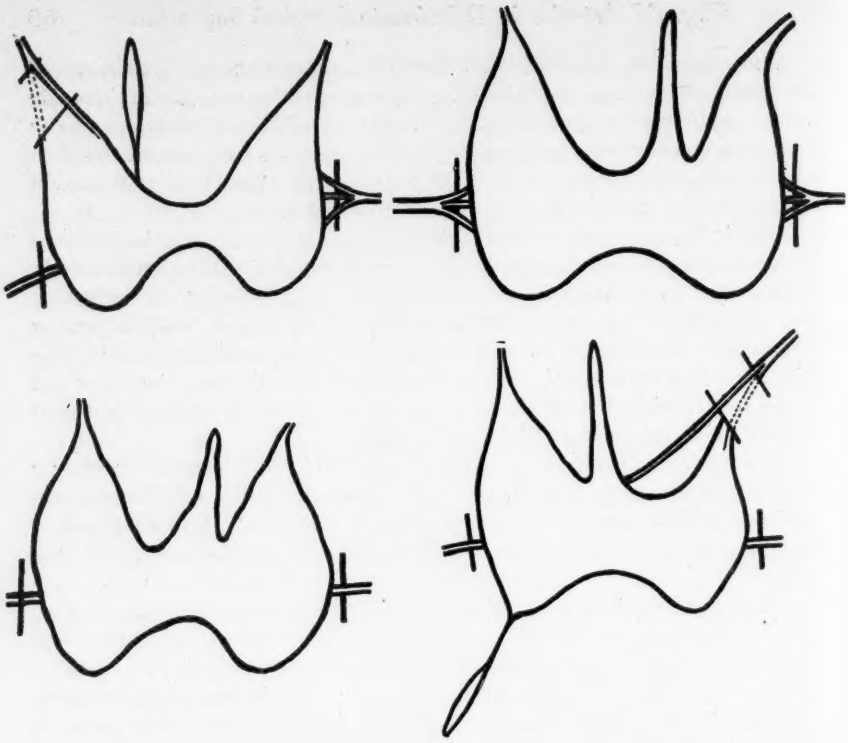

Fig. 2. Drawings made from dissections of the thyroid apparatus, to show the relative size and position of the arteries, and the relationship of the inferior thyroid artery to the recurrent laryngeal nerve. The thyroid lobes have been opened out somewhat by bending forwards.

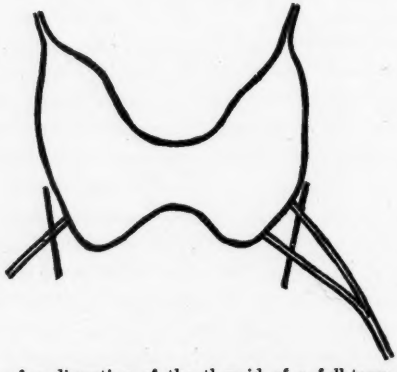

Fig. 3. Drawing made of a dissection of the thyroid of a full-term female foetus, showing relative size of vessels, a duplication of the inferior thyroid artery on the left side, and the relative position of the recurrent laryngeal nerve in relation to the inferior arteries. The thyroid lobes have been opened out somewhat by bending forwards.

through the sterno-mastoid, separating the sternal and clavicular heads, as advocated by Dietrich and Langenbeck, who were apparently the first to practise ligation near the origin of the artery, or behind the sterno-mastoid as practised by Drobnik, Rydygier, Wölfler and others, who approached the artery through an incision along the lower part of the posterior border of the sterno-mastoid and opened up the triangle made by this muscle in front, the posterior belly of the omo-hyoid behind, and the clavicle below.

From dissections on the cadaver I have found that this posterior approach gives a good exposure of the trunk of the inferior thyroid, but that one or two slight modifications of the Drobnik operation can be made with advantage.

The incision is better made in a crease line a finger's breadth above the clavicle, since transverse scars in the natural planes of cleavage in the neck are less conspicuous than oblique or vertical ones, and if an operation is subsequently performed upon the thyroid itself the usual Kocher incision "en cravat" can be made continuous with the scar through which the inferior artery was previously ligated.

I arrived at this conclusion independently, but on subsequently referring to some papers on ligation, found that Rydygier had already advocated this as a modification of Drobnik's operation.

The other modification which was found helpful was to approach the trunk of the artery outside the upper and outer boundary of Drobnik's triangle, formed by the omo-hyoid muscle, a better exposure being obtained by retracting the omo-hyoid downwards than by attempting to pull it upwards so as to open up the triangle.

Ligation of the inferior thyroid artery. The head being extended and slightly rotated to the opposite side, an incision 1½ inches in length is made in a crease line about a finger's breadth above the clavicle, so that its inner end crosses the posterior fibres of the sterno-mastoid (fig. 4).

Fig. 4. Line of skin incision for ligation of inferior thyroid artery. The posterior belly of the omo-hyoid is indicated by dotted lines.

The sterno-mastoid is retracted forwards, and on dissecting through the fascia the tendon of the omo-hyoid is defined and pulled downwards and inwards so as to expose the lower and inner aspect of the scalenus anticus.

In the angle between the upper margin of the retracted omo-hyoid and the inner border of the anterior scalene muscle, and behind and slightly external to the carotid sheath, the artery will be found rising towards the summit of its upwardly directed curve (fig. 5). The vessel can be identified by its origin from the axis, the other branches of which are often seen,

especially the transversalis colli, crossing the lower part of the scalenus anticus. The vertebral artery is altogether more deeply and inwardly placed and quickly sinks through its foramen in the sixth cervical transverse process, the outer part of which constitutes Chassaignac's tubercle which is a guide to the change of direction of the inferior thyroid artery from ascending to transverse. The ascending cervical branch will not be mistaken for the main trunk of the inferior thyroid artery if the line of the main vessel is followed out.

The phrenic nerve is not damaged as it is displaced outwards with the scalenus anticus if retraction of this muscle should be necessary. During the exposure the internal jugular and subclavian veins may appear in the wound and some lymph glands which, if much enlarged, may prove troublesome. It may be necessary to remove these glands to proceed with the exposure of the artery.

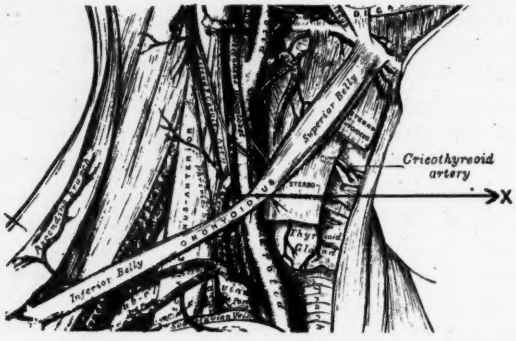

Fig. 5. The anatomy of the inferior thyroid artery (after Gray).[1]
X marks the point at which the ligature is applied.

Owing to its depth and relations the inferior thyroid artery is exposed with care but deliberately: the operation is not difficult and can be carried out under local analgesia. Since working out this route, on the cadaver, I have now performed ligation of the inferior artery by way of it eleven times for toxic goitre. There have been no deaths, and the only slight difficulty has been enlarged lymphatic glands to which reference has been made.

It has been found that the operation is most easily performed upon a spare woman, while the most difficult subject is a well-built man in whom the development of the sterno-mastoid may be such that powerful retraction is necessary to expose the inner border of the scalenus anticus, which muscle may be so well developed also as to necessitate its strong backward retraction to expose the artery. The muscular development also, of course, places the artery at a relatively greater depth in a subject of this type, in whom however toxic goitre is only very rarely met with.

[1] Reproduced by permission of the publishers of Gray's *Anatomy*, Messrs Longmans, Green and Co., Ltd.

COMMENTARY

Evidence has been advanced to the effect that although the superior thyroid is the primitive artery to the thyroid body, the inferior artery is generally the larger and the more important from the point of view of occlusion to reduce the vascularity of goitres, and a route for the exposure and trunk ligation of this vessel has been worked out on the cadaver and practised first in the dissecting room and later in cases of toxic goitre.

A series of dissections has shown that the inferior artery bears a variable relationship to the recurrent laryngeal branch of the vagus. The inferior laryngeal nerve sometimes lies in front of, sometimes behind the artery and sometimes passes through its terminal branches, while the relationship is not constant on the two sides of the body.

When operating in the region of the hilus it is important to bear in mind this very variable relationship, as to the cause of which one is led to speculate because certain other neuro-vascular relationships are so remarkably constant.

It is interesting to reflect on the constancy of relationship of the oculomotor nerve near its origin to the posterior cerebral and superior cerebellar arteries, of the lumbo-sacral trunk to the gluteal artery, the median nerve at the elbow to the more deeply placed ulnar artery with the intervening coronoid head of the pronator radii teres, of the suprascapular nerve passing beneath the transverse scapular ligament to the artery passing over it, and of many other nerve artery relationships. An altered relationship between nerve and artery in these and numerous other examples occurs only very occasionally, but my dissections have shown that it is difficult to fix any characteristic relationship between the recurrent laryngeal nerve and the inferior thyroid artery.

The relationships taken up between nerves and arteries probably come about as the result of the fusions between the branches of the primitive retiform vascular system giving rise to the arterial trunks, the exact course of each of which and therefore the relationship to adjacent nerve fibres, probably depends upon several factors such as the degree of development and change in position of the organ to which the arterial trunk is running. Whether the development of the organ determines the arterial confluence or whether the fusions in the arterial network result in a greater blood supply and greater development of the organ, is debatable, but in the case of the thyroid buds which are undergoing change of position caudally while developing in the direction of their ultimate function, it is clearly possible for the artery to the hilus, coming off the aortic arch, to bear various relationships to the branch of the vagus which hooks round the sixth arch and returns to innervate the larynx.

It is suggested that the inferior artery is a secondary vascularisation and that the complicated development of the thyroid is the cause of this variable nerve artery relationship, since it would appear that the simpler the develop-

ment of a particular organ the simpler and more constant the neuro-vascular relationships in association with it, for as Mr Hamilton Russell once aptly remarked: "it would seem that all the important changes in the development of the embryo are accompanied by the development in the evolving structures of a vascular system, at first absolutely simple and direct in plan, but which, through having to follow the varying contortions of the developing mass, becomes likewise contorted and apparently eccentric in arrangement. I imagine that every artery and every portion of an artery in the body, no matter how tortuous its arrangement may be now, at its inception took the shortest and most direct route from its origin to its termination; its course was, in fact, a straight line, and the arterial tortuosities with which the dissecting-room has made us familiar may be regarded as an accurate, though necessarily imperfect, sketch-in-outline of the embryonic changes that have culminated in the full development of the organ to which the artery is distributed."

In discussing which vessel it is desirable to ligate in cases of toxic goitre, the factors taken into account were the size and importance of the vessel from the point of view of its distribution, and the facility of surgical access to the vessel. Another factor has however to be considered, namely, the nervous innervation of the thyroid and the effect of ligation upon this, since the nerve fibres accompany the vessels. Sympathetic fibres are found with both the superior and inferior arteries, but in addition, running with the upper artery are branches of the external laryngeal nerve which are said to contain vaso-dilator and secretory fibres to the thyroid.

Division between ligatures of the superior vessel near its termination, or polar ligation (the Stamm-Jacobson operation) results in a severance of these external laryngeal fibres and may possibly therefore be of additional, but conceivably not very great, advantage beyond the devascularisation of that part of the thyroid lobe to which the superior artery is distributed.

CONCLUSIONS

1. The inferior thyroid arteries are usually larger than the superior.

2. The inferior artery is the artery of the hilus. It supplies the parenchyma of the gland, and this distribution and its size render it the most important vessel to ligate to reduce the activity of toxic goitres.

3. The inferior artery enters the hilus of the gland at a point which is approximately at the junction of the upper two-thirds with the lower third of the outer border of the gland, but somewhat posteriorly.

4. As a separate operation, ligation of the inferior thyroid artery is best carried out behind the sterno-mastoid by a route described in detail in the text.

5. The superior artery is the primitive artery to the human thyroid and is a constant vessel. It may be compared with the sciatic in the lower limb. After a time the inferior thyroid takes on the principal blood supply as the femoral does in the lower limb.

6. The inferior artery is less constant than the superior. It may be absent on one side. Very rarely it is duplicated on one side.

7. The recurrent laryngeal nerve bears a very variable relationship to the terminal part of the inferior artery or to its branches of distribution. The relationship may vary on the two sides of the body, and the nerve may pass either in front of or behind the artery or thread through its divisions if, as sometimes happens, the artery breaks up before entering the hilus.

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TRUE CONGENITAL DIVERTICULUM OF THE TRACHEA IN A SUBJECT SHOWING ALSO RIGHT AORTIC ARCH

By E. P. STIBBE

Diverticulum of the trachea—sometimes called aerocele—is not an excessively rare condition. Ziegler and Kahlden (1) report a case in 1897 and give a number of references; they discuss at length the causation and pathology of the condition. It would appear that diverticula may be produced as "pulsion-diverticula" in cases of chronic pulmonary and bronchial disease (Rokitansky (2)); the critical pathological feature is a greater or less destruction of the elastic tissue of the bronchi and trachea, as is known in cases of bronchiectasis. According to Gruber (3) tracheal diverticula are retention-cysts of the large mucous glands in the wall of the trachea, which glands are especially large and numerous in the posterior wall of the tube. According to Stirling (4) the acini of the mucous glands of the trachea lie *outside* the trachealis muscle, so that their ducts have to pierce that muscle to open into the lumen of the trachea. He emphasises the large size and number of the glands opposite the trachealis muscle and Bland-Sutton (5) points out that tracheal diverticula "invariably occur near the junction of the trachealis muscle with the cornua of the semi-rings of the trachea."

W. S. Muller (6) gives a full description of the musculature of the trachea. It appears that the transverse fibres constituting this muscle form relatively independent bands. These bands are situated opposite the cartilages, being attached at their extremities to the free ends of the incomplete cartilaginous rings. Between the adjacent bands are relatively amuscular areas—so that the position of the orifice of a diverticulum at a level between two rings would correspond to a weak area in the musculature.

All the cases under any of the above headings are due to pathological causes. Most of them are associated with chronic respiratory disease. A most important anatomical feature of these cases is that the opening into the trachea is relatively large (e.g. 2 cm. × 1½ cm., Ziegler and Kahlden). The special features of the present case are that the opening into the trachea is pin-point in size, and that the histological appearances are those of normal bronchus—except in the absence of cartilage. It would appear therefore to be a true developmental anomaly.

THE SUBJECT

The subject was an adult female aged 46 years, received from an asylum. Death was reported as due to "heart disease," with no report of any noteworthy respiratory condition. An enquiry made from the asylum officer with

respect to this, and also with respect to the existence of any special physical signs—as pulsations—received a negative reply. The subject showed a moderate parenchymatous enlargement of the thyroid gland, and had a right-sided aortic arch and descending aorta as reported below. No other anomaly or important pathological condition was noted.

The tumour was a large rounded cyst-like body wedged in behind the upper part of the manubrium sterni and immediately above the rather high aortic arch. Its position is indicated by the arrow in fig. 1. The upper pole

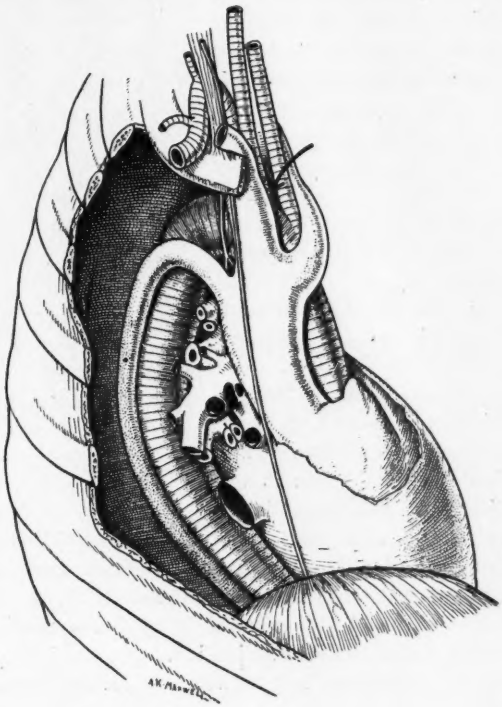

Fig. 1

of the tumour just touched the lower pole of the rather large right lobe of the thyroid. The position, size and shape, and consistency were such that it resembled a thyroid adenoma; had it been palpable during life—which it probably was not—this would have been the diagnosis. The tumour, however, showed no connection with the thyroid gland. It was, on the contrary, freely movable and could be "shelled" out from its bed without any dissection. It was then found to have a long thread-like pedicle which was dissected out down to the back of the trachea about one inch above its bifurcation. A very

fine wire was passed along this pedicle and found to enter the back of the trachea by a pin-point opening; the opening showed definite rounded margins when examined with a hand-lens.

Histological examination (fig. 2) shows a number of irregular rounded spaces containing epithelial debris. The spaces are lined by a double-layered epithelium characteristic of the respiratory tract, namely, a basal layer of cuboidal cells, surmounted by a layer of tall columnar cells with long close cilia on their free edge. Beneath the mucous membrane is loose areolar tissue in the meshes of which are numerous lymphoid corpuscles; in places the lymphoid cells are closely packed. Muscular tissue was not observed, and elastic fibres were sparingly scattered through the section. No cartilage was present.

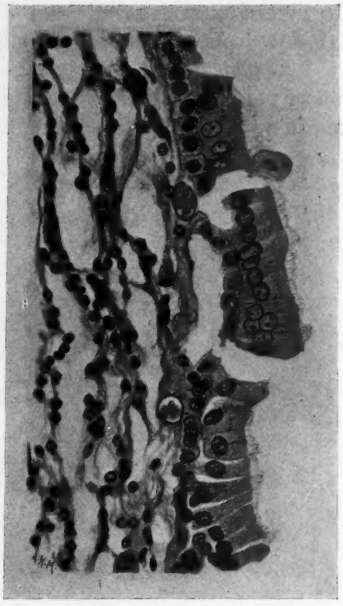

Fig. 2

Section of the trachea shows nothing abnormal, but there is perhaps a diminution in the amount of elastic tissue.

The opening into the trachea was inspected from within the trachea. It shows as a tiny white speck in the posterior wall to the right side of the mid-line: it will just pass a medium-sized pin. Immediately above it are two similar white spots which under a hand-lens are seen to be orifices of mucous glands; there are no external swellings opposite these openings. No histological study was made of the orifice, but the hand-lens was sufficient to show that the tracheal mucosa was continued into the opening—it represented a definite evagination.

The position of the opening was between the levels of two of the cartilaginous rings.

DISCUSSION

This tumour cannot come under the head of any of the types referred to in the introduction. It is not glandular as proved by its histology. It is not a traction diverticulum since it was free from adhesions, and could in fact be dislocated from its bed without any dissection; it can hardly be a pulsion diverticulum with a pin-point opening, and there is no clinical history or post-mortem evidence of important respiratory disease.

The writer believes that the clue to this diverticulum is to be found in the accessory bronchus of Aeby (7). L. Dalla Rosa (8) catalogues eight cases

of supernumerary bronchus and one case of these corresponds with the present in that the bronchus fails to join the lung. The author calls it a congenital tracheal diverticulum, and believes it to be a rudimentary third stem-bronchus.

CONCLUSION

These conditions make it reasonable to suppose that we have here an abortive lung bud—a genuine case of Aeby's supernumerary bronchus. No reason can be found for associating the diverticulum with the abnormal aortic arch described below—except the usual tendency for anomalies to be multiple.

THE AORTIC ARCH OF THE SAME SUBJECT

Right aortic arch without other transposition of viscera is a well-known condition, yet perhaps of sufficient interest to justify the recording of cases as they are observed. The present case is one of the less common varieties—one in which, while the left fourth aortic arch has disappeared, the left dorsal aorta from the level of the fourth arch to the junction of the two dorsal aortae has persisted to form the left subclavian artery. This type of variation is figured by Quain (9) and has been described in the adult by D. G. Reid (10) and in a foetus by Garnier and Villemer (11).

On opening the thorax the arch of the aorta looked normal in direction, but on further investigation it was seen (fig. 1) that

(*a*) it was longer than usual, rising to the body of the third thoracic vertebra;

(*b*) the left common carotid arose from the ascending aorta about one inch from its commencement;

(*c*) the arch turned towards the left for a short distance, and then with a sharp kink turned backwards and downwards across the body of the third thoracic vertebra to the fourth, where it diverged to the right; subsequently its course down the right side of the vertebrae was as that of the normal descending aorta on the left.

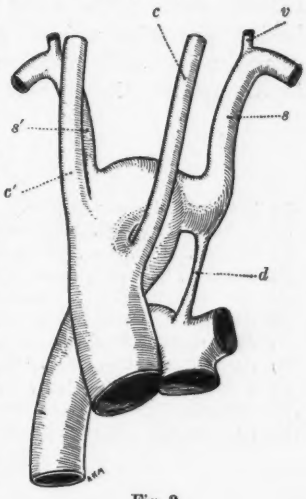

Fig. 3

Branches (fig. 3). The left common carotid (*c*) was the first branch as mentioned.

The right common carotid (*c'*) and subclavian (*s'*) came off separately at a position on the right side symmetrical with the usual left-side position; there was no innominate artery.

The left subclavian (*s*) comes off from the point where the arch turns suddenly back prior to taking its turn to the right; but the proximal part of

this subclavian is almost as large as the aorta, and abruptly narrows down to normal subclavian size about three-quarters of an inch from the aortic arch. This origin of the subclavian lies behind the trachea.

The ductus arteriosus (*d*) connects the junction of the pulmonary arteries to the subclavian just at the point where the latter becomes of normal size.

The right vagus nerve crosses the first part of the right subclavian artery and the right side of the arch; the right recurrent laryngeal nerve hooks round the aortic arch. The left vagus runs down in front of the first part of the subclavian artery, and the left recurrent nerve hooks up behind the ductus arteriosus.

COMMENT

This is one of the less common forms of right aortic arch, but is a well-recognised variety. It corresponds, for example, precisely and in all its details to the third case of Reid (10) and its embryology is not difficult to decipher. No doubt the left common carotid represents the left branch of the ventral aorta as far as the third left arterial arch. Since this artery is normally formed from the third arch and that part of the ventral aorta between the third and fourth arches, it now includes the part of the ventral aorta which lies between fourth and fifth arches. This included vessel is that which normally forms innominate on the right side. In this case it forms the aortic arch on the right side—hence the absence of innominate. The pouch-like origin of the left subclavian is the distal part of the left dorsal aorta, extending from behind the trachea upwards and to the left to join the subclavian at a point corresponding to the usual origin of that vessel from the fourth arch; the fourth arch itself is missing.

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VALVES IN VEINS: FURTHER OBSERVATIONS

By K. J. FRANKLIN, D.M.

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Two horses provided the material for dissection, and from them were taken, among others, four jugular veins and one left renal vein with the portion of inferior vena cava above and below its entry.

In the inferior vena cava (fig. 1), below the ostial valve at the renal vein entry, there were two single cusps (*ab*), the lower one guarding a small recess

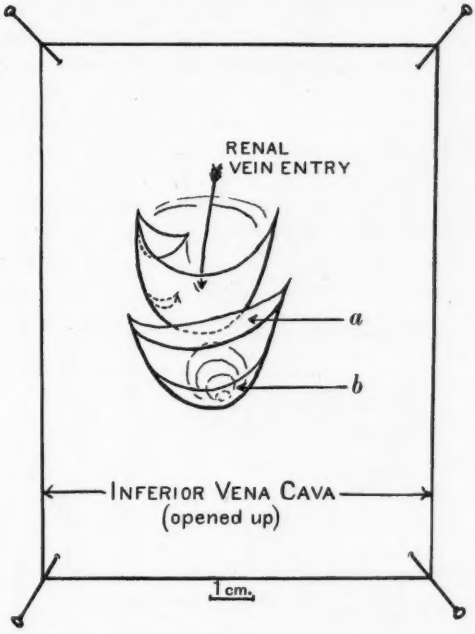

Fig. 1

in the vein wall. This recess looked as if it might once have been a tributary entry, but there was no macroscopic trace of any such vein. This finding must therefore be added to that of Bardeleben (1), the only other record of a valve—not ostial—in the inferior vena cava between the heart and iliac veins. Bardeleben's valve was also an unicuspid one. The figure represents the portion of vena cava slit open longitudinally.

In the jugular veins two new features of interest were disclosed:

1. Three examples occurred in two jugular vein specimens where one cusp of a valve in a vein, at its junction with a second vein, was formed by a portion of vessel wall common to both veins. Fig. 2, which shows two of

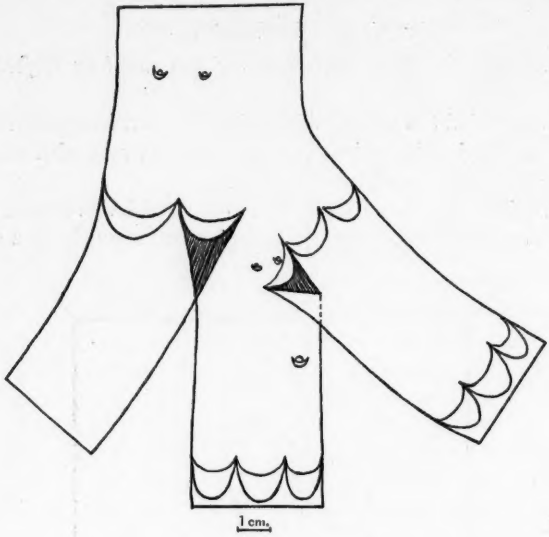

Fig. 2

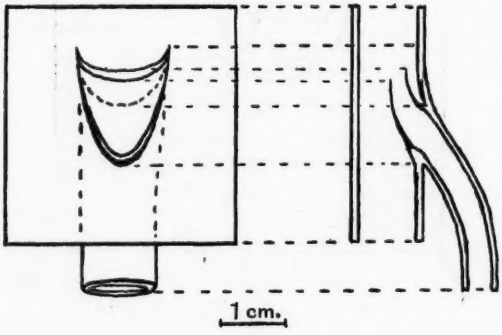

Fig. 3

these cases, is a drawing of three tributaries joining to form the large jugular vein. The shaded portions represent the parts common to two veins, apart from the cusps. All the veins have been slit open longitudinally.

2. In a third jugular vein the entries of three lesser veins had valves arranged as in fig. 3, which is a drawing of the largest of these three. In the

left half of the figure is represented a portion of the jugular vein slit open longitudinally to show the tributary entry. In the right half is a reconstruction of the vein and tributary in longitudinal section. Injection of the jugular vein before it was slit up was blocked by this double valve both in the main vein and in the tributary, so the outer cusp must have blocked the main vein (although its inter-cornual distance was only two-fifths of the vein circumference), and the inner cusp, attached to the posterior wall of the tributary, must have folded over on to the outer cusp and blocked the tributary. It is believed that this type of double valve and its action have not before been described. The two cusps had in common the upper part of the cornua.

A method of mounting a section of everted vein, which allows of illumination from inside, is shown in fig. 4. An outer glass tube holds the mounting fluid and is closed by corks (shaded in the figure) at top and bottom. An inner glass tube, over which the everted vein is drawn, fits tightly over the cork in the bottom of the outer tube and comes up through the larger cork in its top. A mercury check (solid black in the figure) lies at the bottom of the inner tube as a precaution against any leak of fluid from the outer tube. A small electric bulb can be let down inside the inner tube to any level, and by its light one can see a large amount of the fibrous network of the cusps described and pictured by Pettigrew (2). Or the tube may be filled with coloured fluid.

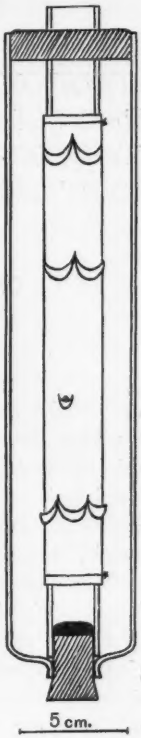

Fig. 4

SUMMARY

A rare occurrence of valves—not ostial—in the inferior vena cava is described, also two new findings on valves, and a new method of mounting veins containing valves.

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DEVELOPMENT OF THE INFERIOR VENA CAVA IN THE LIGHT OF RECENT RESEARCH, WITH ESPECIAL REFERENCE TO CERTAIN ABNORMALITIES, AND CURRENT DESCRIPTIONS OF THE ASCENDING LUMBAR AND AZYGOS VEINS

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INTRODUCTION

Since the publication of Rathke's, Kerschner's and Hochstetter's pioneer researches on the development of the venous system, a large amount of admirable work has been carried out on the development of the postrenal part of the inferior vena cava, both in animals and in man. The bulk of this work has been accomplished by American embryologists and more especially by Lewis, Miller, Huntington, McClure, Butler, Sabin and Reagan.

The older methods of reconstruction have now been supplemented by the intravascular injection of solutions of Indian ink, nitrate of silver, Prussian blue, and other dyes, into living embryos, the tissues being afterwards fixed, cleared and mounted in celloidin. This method has furnished most beautiful demonstrations of the finer vessels and their anastomoses, even in quite young embryos, e.g. rat embryos having only 2–3 somites (Reagan). But although, under exceptional circumstances, the successful injection of a living human embryo has been accomplished (Broedel), the careful study and reconstruction of serial sections of human embryos is still the most valuable method of research with regard to the development of these blood vessels in man.

COMMENTS ON CURRENT DESCRIPTIONS OF THE ASCENDING LUMBAR AND AZYGOS VEINS

In three papers written before the publication of the more recent work of the above-mentioned authors, I recorded: (A) two cases of a dorsal position of the ureter relative to the inferior vena cava; (B) one of a postaortic course of the left renal vein; and (C) one of a left postrenal vena cava. In the article dealing with the postcaval position of the ureter, I drew attention to the development of the ascending lumbar vein, by the formation of a longitudinal anastomosis between the lumbar intersegmental veins. This vessel courses vertically in front of the transverse processes of the lumbar vertebrae, and behind the psoas major muscle (fig. 6 of that article).

ERRATUM

JOURNAL OF ANATOMY

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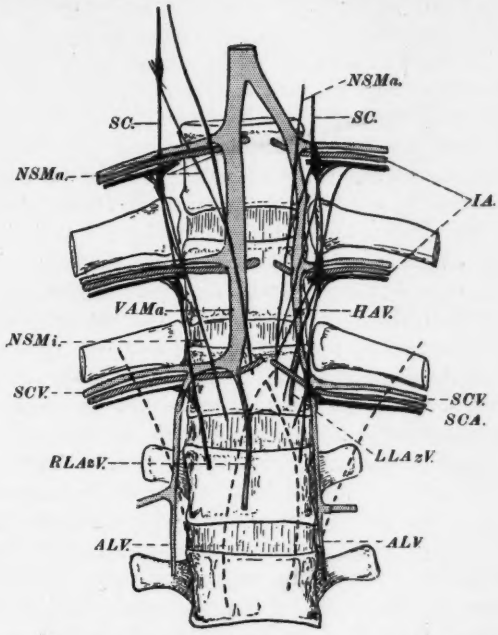
In Text-fig. 1 of Dr R. J. Gladstone's paper on the Development of the Vena Cava etc., the splanchnic nerves should have been represented as lying in front of the intercostal arteries and not behind them.

The course of an anastomotic vein (text-fig. 1), which commonly arises from the dorsal aspect of the inferior vena cava, and proceeds upwards through the right crus of the diaphragm, or its aortic opening, to join the vena azygos major in front of the body of either the 12th or 11th thoracic vertebra, was also commented on, and figured. A similar anastomotic vein is frequently present on the left side, and passes into the thorax through the left crus of



Text-fig. 1. Drawing from an adult male subject showing the origin of the vena azygos major and vena azygos minor; and the relation of these vessels to the sympathetic chain, the splanchnic nerves, and the intersegmental arteries. The dotted lines indicate the position of the crura of the diaphragm.

ALV.	Ascending lumbar vein.	*NSMi.*	Lesser splanchnic nerve.
IA.	Intercostal arteries.	*RLAzV.*	Right lumbar azygos vein.
HAV.	Hemiazygos vein.	*SC.*	Sympathetic cord.
LLAzV.	Left lumbar azygos vein.	*SCV.*	Subcostal vein.
NSMa.	Greater splanchnic nerve.		

the diaphragm (text-fig. 1); this vein may arise from a left lumbar vein, the left renal vein or the inferior vena cava, and it usually joins the hemiazygos vein at the level of the body of the 12th thoracic vertebra.

The first accurate description of these anastomotic veins in the adult human subject, in this country, was by Robinson (22), who figured five cases, showing the origin of the right anastomotic vein, from the dorsal aspect of the inferior vena cava, at a point below the termination in it of the renal

veins; and he also drew attention to the frequent termination of the 1st, and sometimes the 2nd lumbar vein in the anastomotic vein of the corresponding side. Unfortunately, however, although well aware of the relations, he did not in this paper make any allusion to the termination of the subcostal vein which unites, as is correctly described in the majority of textbooks on human anatomy, with the ascending lumbar vein. This union normally takes place behind the origin of the diaphragm, close to the head of the 12th rib, and by the side of the body of the 12th thoracic vertebra. On the right side the vein which is formed by the union of the subcostal vein with the ascending lumbar vein is regarded as the commencement of the vena azygos major, and the similar vein on the left side as the commencement of the vena azygos minor or hemiazygos vein. The subcostal vein passes into the thorax beneath the lateral lumbocostal arch; the ascending lumbar vein passes upward behind the psoas muscle, and beneath the medial lumbocostal arch. The vena azygos major then ascends in the thoracic cavity for a distance of one or two inches, before it is joined by the slender anastomotic vein (sometimes merely a fibrous cord, text-fig. 3), which ascends *in front* of the vertebral column either through the right crus of the diaphragm or its aortic opening. The statement therefore that the vena azygos major passes through the aortic opening of the diaphragm does not accord with the description of the origin of the vena azygos major, from the junction of the right subcostal vein, with the right ascending lumbar vein; and since the anastomotic vein in many cases does not pass through the aortic opening, but traverses the right crus of the diaphragm, and is sometimes represented only by an impervious cord, it is obvious that the alternative description of the vena azygos major arising in the abdomen from an "ascending lumbar vein" in front of the vertebral column and psoas muscle and passing through the aortic opening of the diaphragm is inconsistent with the more classical description of its origin in the thorax from the junction of the right subcostal vein with the ascending lumbar vein, namely, that vein which lies behind the psoas major muscle, and in front of the transverse processes of the lumbar vertebrae.

The necessity for a more exact description and drawings of the ascending lumbar veins, and of the origin of the vena azygos major, will be apparent on comparing the statements which are quoted below from current textbooks on human anatomy:

(1) The vena azygos major or right azygos vein commences in the abdomen, as the right ascending lumbar vein, and enters the thorax through the aortic opening of the diaphragm, lying on the right side of the aorta, the thoracic duct intervening. The ascending lumbar vein is depicted in a figure on the succeeding page as passing upward in front of the psoas muscle, although it is correctly described in the text under the heading of the Lumbar Veins: The vessels of each side are connected by a series of longitudinal anastomosing veins, in front of the lumbar transverse processes, and the longitudinal vessel thus formed is called the *ascending lumbar vein.*

(2) The azygos vein (O.T. vena azygos major) usually takes origin in the right ascending lumbar vein. It will be found in the interval between the right crus of the diaphragm and the aorta, upon the right side of the cisterna chyli, and it will

be noticed to enter the thorax by passing through the aortic opening....The vena azygos commences in the abdomen where it anastomoses either with one of the upper lumbar veins or directly with the inferior vena cava.

(3) Between the crura and to the right of the aorta lies the right ascending lumbar vein, a longitudinal trunk linking together the transversely coursing lumbar veins, which pass inwards from under cover of the fibrous arches of the psoas to open into the inferior vena cava. This ascending lumbar vein is the beginning of the vena azygos major, but the latter vessel always has a communication with the back of the inferior vena cava as well. In many cases the ascending lumbar vein is hardly visible, and then the vena azygos rises entirely from the inferior vena cava.

(4) The larger or right azygos vein commences opposite the first or second lumbar vertebra, by a branch from the right lumbar veins (the ascending lumbar); sometimes by a branch from the right renal vein, or from the inferior vena cava. It enters the thorax through the aortic opening of the diaphragm.

(5) The vena azygos major begins in the abdomen, where it may be looked upon as the continuation upwards of the ascending lumbar vein. It passes through the aortic opening of the diaphragm....The trunk lumbar veins are connected beneath the psoas muscle by vertical branches, which cross in front of the transverse processes.

I would suggest that the term "ascending lumbar vein" be limited to the vertical precostal anastomosis, which extends between the iliolumbar vein and the termination of the subcostal vein; in other words, the longitudinal vessel behind the psoas major muscle which commences below in the iliolumbar tributary of the common iliac vein, and terminates above by uniting with the subcostal vein, to form on the right side the vena azygos major, and on the left side the vena azygos minor or hemiazygos vein.

I would also suggest that the small anastomotic vein which commences on the dorsal aspect of the inferior vena cava or from one of its tributaries near the termination of the right renal vein, and passes upward through the aortic opening of the diaphragm to join the vena azygos major, be called the *right lumbar azygos vein*; further that the classical description of the origin of the vena azygos major, by the union of the right ascending lumbar vein with the right subcostal vein, be retained, and as a corollary to this, that the description of the vena azygos major commencing in the abdomen as a continuation of the ascending lumbar vein and entering the thorax through the aortic opening of the diaphragm be discarded altogether.

Moreover, I would suggest that the corresponding vein on the left side, which passes upward in front of the vertebral column, and through the left crus of the diaphragm, be termed the *left lumbar azygos vein*, since both in the embryo and in the adult it has similar relations to those of the right side, with the exception that it usually arises from the dorsal aspect of the left renal vein (intersubcardinal anastomosis), or one of its tributaries, instead of directly from the inferior vena cava. Moreover, the vena azygos minor might be appropriately defined as arising by the junction of the left ascending lumbar vein with the left subcostal vein, and receiving as a tributary a short distance above its origin the small left lumbar azygos vein.

The employment of the terms "azygos" (without a yoke) and "hemi-

azygos" (half unyoked) is obviously incorrect. These names, however, have become so ingrained by long usage, that although from the academic standpoint it would be advantageous to replace them by a better term, from the practical standpoint it would be difficult to discontinue these old-established and familiar terms.

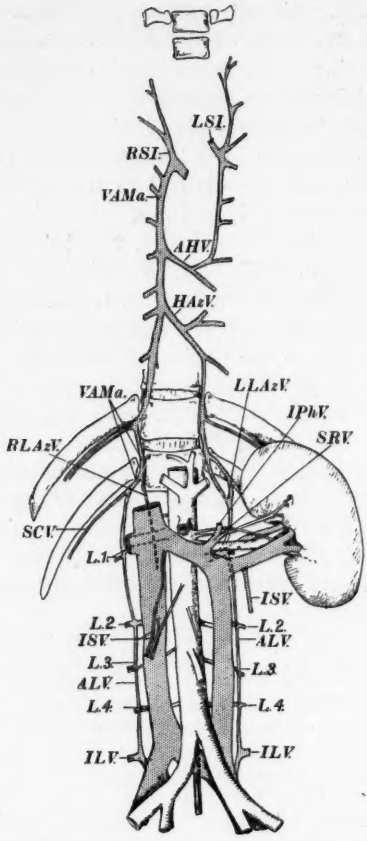
In addition to the use of the term "lumbar azygos veins" for the veins in the lumbar region, which are homologous with and continuous with the thoracic azygos veins, it will be necessary to explain the following terms which are applied by various authors to certain embryonic veins in this region: (1) Thoraco-lumbar veins described by Hochstetter and later defined by Reagan. These lie ventrolateral to the sympathetic chain and the nerves passing from the ganglionated chain to the preaortic plexuses; for a brief period these veins receive the segmental drainage which has been abandoned by the posterior cardinal veins; at a later stage of development they are succeeded by the medial parasympathetic veins, or permanent azygos system. (2) Medial parasympathetic veins (Reagan). These are in the azygos line and are used as synonyms for the azygos veins in the lower thoracic and lumbar regions. They lie medial to the sympathetic chain, dorsomedial to the nerves passing from the chain to the preaortic plexuses, and ventrolateral to the thoracic and lumbar intersegmental branches of the aorta. (3) Periganglionic plexus of veins (Frazer); "a plexus of veins formed around the groups of sympathetic ganglion cells as these pass out from the posterior root ganglia." It joins laterally with the intersegmental veins, ventrally with the postcardinal and subcardinal veins, and it extends forwards to form a preaortic plexus, from which the intersubcardinal anastomosis is derived. It is also carried down into the pelvis dorsal to the umbilical arteries, and here appears to give rise to the common iliac veins, by an anastomosis in front of the caudal aorta (middle sacral artery) similar to the preaortic anastomosis which forms the terminal part of the left renal vein. He suggests also that the seeming continuity of the postcardinal veins with the pelvic vessels is due to these being derived originally from a continuation of the periganglionic plexus into this region. (4) The thoracic and lumbar supracardinal veins. These are described by Huntington and McClure as well defined, bilateral veins which are situated in the azygos lines. They are formed in the embryos of many mammals as well as in man, one on each side of the aorta, and are united more especially in the lumbar region by numerous postaortic anastomoses; the postrenal section of the vena cava was originally described as arising from the fusion of the right and left supracardinal veins, by enlargement of these anastomoses and disappearance of the spaces between them. In the human subject they succeed and replace the temporary thoraco-lumbar veins in the lower thoracic and upper lumbar regions, where they give rise to the "azygos" veins. In the lower lumbar region the right supracardinal vein gives rise to the inferior vena cava below the level of the renal veins. This part of the right supracardinal vein corresponds to the right paraureteric vein of Reagan,

and a part of the postrenal section of the periganglionic plexus of Frazer. (5) Prevertebral plexus of Sabin, a general term for the veins lying in front of the vertebral column, which give rise to the azygos veins and postrenal vena cava. (6) Subcentral veins which differ from the azygos veins in lying dorsomedial to the origins of the intercostal and lumbar arteries, or in other words between the origins of these vessels. (7) The postrenal anastomosis or posteromedial limb of the venous ring which encircles the metanephros (Hochstetter). (8) Paraureteric vein (Reagan). This vessel lies medial to the kidney and ureter, and ventrolateral to the nerves, passing from the sympathetic chain to the preaortic plexuses.

The lumbar azygos veins, Plate II, figs. 2 and 4, like the lower part of the thoracic azygos veins, Plate II, fig. 1, lie medial to the sympathetic trunks; dorsomedial to the splanchic nerves, text-fig. 1, and the nerves passing from the sympathetic chain to the preaortic and hypogastric plexuses, and they are situated ventrolateral to the origins of the lumbar segmental arteries. These relations of the azygos line of veins to the sympathetic nerves are well known, but the credit of appreciating the importance of their topographical relations in the study of the development of the inferior vena cava is entirely due to Dr F. T. Reagan. The significance of their position with regard to the preaortic plexuses and lumbar arteries will be referred to later.

DESCRIPTIONS OF ABNORMAL INFERIOR VENAE CAVAE

Specimen 1 (text-fig. 2). This is a typical example of the arrangement of veins in this class of anomaly, namely, bilateral postrenal vena cava. The left inferior vena cava commenced in front of the body of the 5th lumbar vertebra, from the left common iliac vein, which vessel, having given origin to the left inferior vena cava, passed obliquely upward behind the origin of the right common iliac artery, to join with the right common iliac vein in forming the right inferior vena cava. The left vena cava coursed vertically upward beside the aorta to the level of the termination in itself of a lower left renal vein. It then turned to the right and crossed the aorta below the origin of the superior mesenteric artery; finally it joined the right vena cava in front of the origin of the right renal artery. This terminal part of the left inferior vena cava received an upper left renal vein, and a venous trunk formed by the union of the left suprarenal vein with the left inferior phrenic vein. The left spermatic vein joined the lower left renal vein. The left ascending lumbar vein commenced as an upward continuation of the lumbar tributary of the left iliolumbar vein, which vessel opened below into the left common iliac vein. The left ascending lumbar vein passed upward behind the psoas major muscle, and finally ended in the upper of the two left renal veins. It received the 5th, 4th and 3rd left lumbar veins, the 3rd and 4th being continued medially from the ascending lumbar vein into the left inferior vena cava. Nearly opposite the termination of the ascending lumbar vein in the left renal vein, a vein (which represents the left anastomotic or lumbar azygos vein) passed upwards behind the principal left renal artery and two accessory renal arteries, towards the vertebral end of the 12th rib, below which it divided into two branches; the lateral of these joined the subcostal vein, and the medial joined the common trunk formed by the union of the lateral branch with the subcostal vein in front of the head of the last rib.



Text-fig. 2 (Specimen 1). Bilateral postrenal vena cava. Note the termination of the right lumbar azygos vein in the vena azygos major at the level of the 12th thoracic vertebra, and its origin from the dorsal aspect of the inferior vena cava below the entrance of the renal veins; also the origin of the left lumbar azygos vein, in common with the upper left renal vein from a corresponding position on the other side. The ascending lumbar veins which lie close to the vertebral column, and behind the psoas muscles and inferior venae cavae, have been represented in the drawing more lateral than their true position.

AHV.	Accessory hemiazygos vein.	*LLAzV.*	Left lumbar azygos vein.
ALV.	Ascending lumbar vein.	*LSI.*	Left superior intercostal vein.
HAzV.	Hemiazygos vein.	*RLAzV.*	Right lumbar azygos vein.
IPhV.	Left inferior phrenic vein.	*RSI.*	Right superior intercostal vein.
ILV.	Iliolumbar vein.	*SCV.*	Subcostal vein.
ISV.	Internal spermatic vein.	*VAMa.*	Vena azygos major.
L. 1, 2, 3, 4.	Lumbar intersegmental veins.		

The right inferior vena cava was formed in the usual way by the junction of the right and left common iliac veins, and from thence upward it pursued the ordinary course of the inferior vena cava on the right of the aorta. It may be noted that this case supports the statement made by Cameron that the right iliolumbar vein joins the common iliac vein at a higher level than the termination of the left iliolumbar vein in the left common iliac vein; and also that on neither side was there a direct communication with or termination of the 5th lumbar vein in the inferior vena cava. Owing to this relation, Cameron conceived the terminal part of the left common iliac vein (interiliac anastomosis) as representing in the adult the enlarged terminal segment of the left 5th lumbar vein. The right ascending lumbar vein had similar relations to those of the left ascending lumbar vein. It passed upward behind the psoas muscle, and terminated above by passing beneath the medial costolumbar ligament, joining the right subcostal vein in front of the head of the last rib. An anastomotic or right lumbar azygos vein commenced from the posterior aspect of the inferior vena cava below the entry of the right renal vein, passed upward through the right crus of the diaphragm, and joined the azygos vein at the level of the 12th thoracic vertebra.

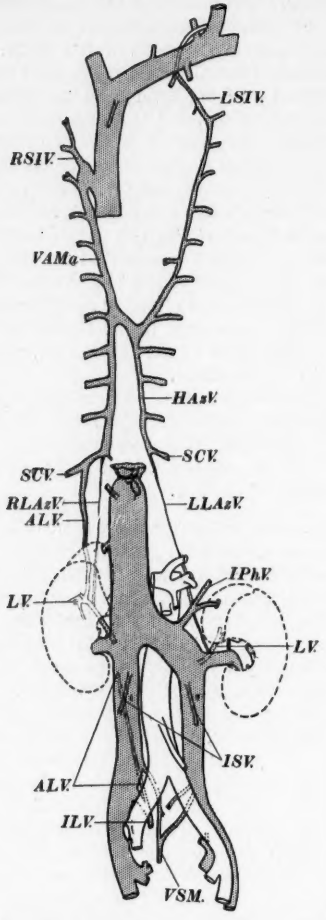
There were two right spermatic veins. One of these joined the right inferior vena cava at the level of the 3rd lumbar vertebra, the other terminated at the angle of junction of the left with the right inferior vena cava.

In the thorax the hemiazygos vein crossed the body of the 9th thoracic vertebra; the accessory hemiazygos that of the 8th.

Specimen 2 (text-fig. 3). Bilateral postrenal vena cava. A complete description of all the vessels is unnecessary, since the general arrangement of the veins is indicated in the drawing. The middle sacral vein divided into right and left branches, each of which joined the corresponding postrenal segment of the inferior vena cava. The anastomotic or lumbar azygos vein of the right side appeared to arise from the 1st lumbar vein. The terminal part of this vein, however, which runs obliquely downwards to join the vena cava, probably represents the primary origin of the anastomotic vein from the dorsal aspect of the inferior vena cava, close to the termination of the right renal vein. It received a communicating branch from the right ascending lumbar vein, namely, a part of the first lumbar segmental vein. On tracing the anastomotic vein upward it became reduced to a fibrous cord, which traversed the right crus of the diaphragm, and finally becoming pervious in its upper part ended in the vena azygos major, in front of the 12th thoracic vertebra.

The left anastomotic or lumbar azygos vein commenced in a similar manner from a common trunk, which received the 1st and 2nd left lumbar veins. This trunk vein terminated below in the left inferior vena cava, at the level of the entrance into it of the left renal vein. On tracing the anastomotic vein upward it was found to terminate in a fibrous cord, which traversed the left crus of the diaphragm and, finally becoming pervious, joined the vena azygos minor.

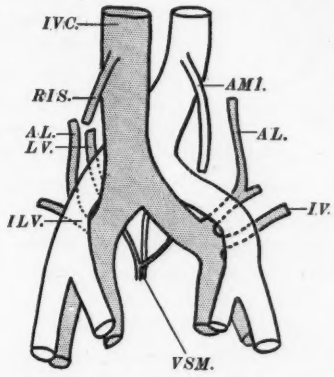
Specimen 3 (text-fig. 4) is an example of the formation of the inferior vena cava, in front of the right common iliac artery. It occurred in a male subject. The middle sacral vein, near its termination, divided into right and left branches, which ended one on each side in the corresponding common iliac vein. The right common iliac vein was joined on its posterior aspect by two veins; one an iliolumbar vein, the lumbar branch of which was continuous above with the ascending lumbar vein, the other a descending lumbar vein which received tributaries from the psoas muscle and spinal canal. On the left side the common iliac vein received a separate iliac vein and a normal iliolumbar vein which was continuous by means of its lumbar branch with the ascending lumbar vein of the same side. A large right internal spermatic vein joined the inferior vena cava at a level corresponding with the origin of the inferior mesenteric artery from the abdominal aorta.



Text-fig. 3 (Specimen 2). Bilateral postrenal vena cava. The central part of each lumbar azygos vein is reduced to a fibrous cord. Above, each fibrous cord becomes patent and joins the thoracic azygos vein of the corresponding side. Below, the right lumbar azygos vein after being joined by the first and second lumbar veins terminates in the inferior vena cava. The left lumbar azygos vein ends below in a similar manner, after having been joined by the upper lumbar veins of the left side. It terminates on the dorsal surface of the left inferior vena cava where this is joined by the left renal vein.

ALV.	Ascending lumbar vein.	*LSIV.*	Left superior intercostal vein.
HAzV.	Hemiazygos vein.	*RLAzV.*	Right lumbar azygos vein.
IPhV.	Inferior phrenic vein.	*RSIV.*	Right superior intercostal vein.
ILV.	Iliolumbar vein.	*SCV.*	Subcostal vein.
ISV.	Internal spermatic veins.	*VAMa.*	Vena azygos major.
LV.	Lumbar intersegmental veins.	*VSM.*	Vena sacralis media.
LLAzV.	Left lumbar azygos vein.		

Specimen 4 (text-fig. 5). The most noticeable peculiarities of this case are: (1) The very large size of the inferior vena cava. (2) The presence of a large vein on the left side of the abdominal aorta, which commenced in a plexus of dilated veins situated in the broad ligament of the uterus; it ascended in front of the internal iliac vessels and ureter, then passed upwards on the psoas major muscle, lateral to the sympathetic chain and in front of the left ovarian artery; just below the level of the origin of the inferior mesenteric artery it received the left ovarian vein, which joined it obliquely from the outer side; near the upper pole of the left kidney it was joined by the left renal vein; the common trunk thus formed crossed the abdominal aorta below the origin of the superior mesenteric artery, and then terminated in the inferior vena cava; this common trunk received (A) a superior polar vein from the left kidney which passed behind the suprarenal body, (B) the left suprarenal vein, and (C) the left inferior phrenic vein. The left kidney was unusually low in position and the left renal vessels were thus obliquely placed and much elongated. (3) The right ovarian vein received an accessory inferior polar vein from



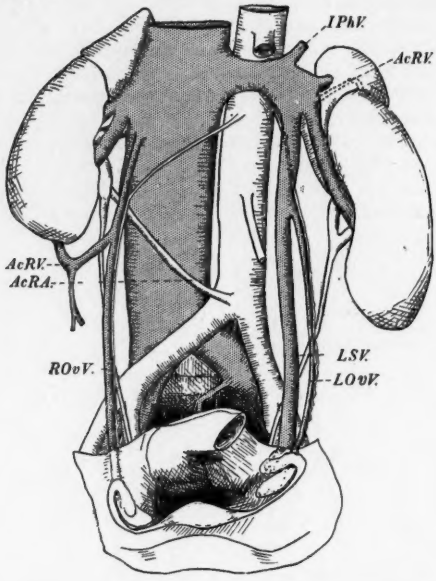
Text-fig. 4 (Specimen 3). Origin of the inferior vena cava ventral to the right common iliac artery.

AL.	Ascending lumbar vein.	*IVC.*	Inferior vena cava.
AMI.	Inferior mesenteric artery.	*LV.*	Lumbar vein.
ILV.	Iliolumbar vein.	*RIS.*	Right internal spermatic vein.
IV.	Iliac vein.	*VSM.*	Middle sacral vein.

the kidney of the corresponding side; this vessel received a tributary which ascended from the retroperitoneal fatty tissue below the kidney, and crossed in front of the right ureter. (4) An accessory renal artery arose from the ventral aspect of the abdominal aorta just above its bifurcation, and ascended obliquely over the inferior vena cava, to reach the hilum of the right kidney. It was crossed superficially by the ovarian vessels and the pelvis of the ureter.

Specimen 5. In this case the inferior vena cava was normal in position, but was joined by a large vein from the left side, which passed behind the abdominal aorta at the level of the origin of the inferior mesenteric artery. This vein commenced near the hilum of the kidney from the lower border of the left renal vein. It was joined here from below by a short common trunk formed by the union of two left ovarian veins. It was joined from above by a tributary which descended in the retroperitoneal fatty tissue, and from below by the 3rd left lumbar vein. It was also joined from below, near its termination, by a prevertebral or subcentral vein, which ran upwards to it behind the abdominal aorta. The 4th left lumbar vein crossed

behind the aorta about 2 cm. below the large postaortic tributary from the left renal vein. The main left renal vein crossed in front of the aorta in the usual position below the origin of the superior mesenteric artery. The right ovarian vein ended in the inferior vena cava in the usual manner a short distance below the termination of the right renal vein.



Text-fig. 5 (Specimen 4). Persistence of left subcardinal vein. Accessory renal veins and accessory renal artery. The large vein on the left side of the abdominal aorta commenced in a plexus between the layers of the broad ligament, crossed in front of the iliac vessels, the ureter and left ovarian artery and terminated in the left renal vein.

AcRA. Accessory renal artery.
AcRV. Accessory renal veins.
IPhV. Inferior phrenic vein.
LOvV. Left ovarian vein.
LSV. Persistent left subcardinal vein.
ROvV. Right ovarian vein.

There were two ovarian arteries on the right side, one springing from the front of the aorta below the left renal vein, crossed behind the inferior vena cava, the other arose from the aorta below the origin of the inferior mesenteric artery, crossed obliquely over the lower part of the inferior vena cava, and joined the former vessel below the level of the bifurcation of the aorta. An excellent drawing of this specimen by Francis W. Kemp is contained in the *Record of Anatomical Variations*, King's College, London, 1915.

REVIEW OF THE DEVELOPMENTAL HISTORY OF THE INFERIOR VENA CAVA

The explanation of these anomalies will be facilitated by a review of the normal development of the inferior vena cava in man, and this will help to substantiate further the comments which I have made earlier in this paper regarding the ascending lumbar and azygos veins. Such a revision of recent work is of especial importance at the present time, since although there is full agreement on the mode of development of the inferior vena cava in its earlier stages, there are fundamental differences of opinion with regard to the later stages. Taking into consideration the important pioneer work of the authors cited in the appended list of references which forms the foundation of our knowledge of this subject, and with the help more particularly of the recent work of McClure and Butler in the human subject; of Reagan and Tribe in the rabbit, and of Reagan and Robinson in man and the carnivora, I venture to give the following brief summary of what I believe to be the main features of the development of the inferior vena cava and azygos system of veins in man.

Commencing with the bilaterally symmetrical venous system of a 4 mm. human embryo (McClure and Butler), it is seen that at this stage there are two large posterior cardinal veins which commence in the caudal region and terminate cranially by joining with the anterior cardinal veins to form the ducts of Cuvier. They receive visceral tributaries from the Wolffian bodies and somatic intersegmental veins from the body wall and spinal cord. They are also connected by anastomoses with the two small subcardinal veins which lie in the mesonephros near the root of the mesentery. Each subcardinal vein ends anteriorly in the posterior cardinal vein of the corresponding side. The posterior cardinal veins lie dorsolateral to the umbilical arteries, and extend a considerable distance in the caudal region beyond these, and the caudal ends of the mesonephroi. The part of each posterior cardinal vein which extends beyond the mesonephros, and receives tributaries from the body wall, may be distinguished as the *pelvic segment*, and its drainage is mainly somatic. That part of each posterior cardinal vein which receives tributaries from the mesonephros, as well as from the body wall and spinal cord, is the *mesonephric segment*, and the part which extends headward from the termination in it of the anterior end of the subcardinal vein to the duct of Cuvier may be distinguished as the *terminal thoracic segment*.

In the 10–11 mm. stage represented by the reconstruction models of McClure and Butler, the two subcardinal veins are connected across the front of the abdominal aorta by a plexus of veins, the preaortic intersubcardinal anastomosis. This lies below or caudal to the origin of the superior mesenteric artery. The primary connection of the anterior ends of the subcardinal veins with the posterior cardinal veins has now been interrupted. Further, the important connection of the right subcardinal vein with the hepatic sinuses

and the common hepatic vein is already established, as is also the interiliac anastomosis between the posterior cardinal veins. This anastomosis is situated below the bifurcation of the abdominal aorta, and between the umbilical arteries (which curve forward ventral to it) and the middle sacral artery which lies dorsal to it. The terminal part of the left common iliac vein is thus already laid down and in McClure and Butler's reconstruction of a 10–11 mm. embryo, and in four of my own specimens (9, 10, 11 and 12 mm. in length), the succeeding part of the right posterior cardinal vein is considerably larger than the corresponding part of the left posterior cardinal vein. Moreover, this part of the postcardinal vein is displaced in a dorso-lateral direction, by the growth of the permanent kidney; the posterior cardinal vein thus forms a C-shaped bend round the outer border of the kidney, the umbilical artery intervenes between the vein and kidney. Ventral to the metanephros and medial to the umbilical artery on each side is the caudal end of the subcardinal vein and the vein which drains the caudal end of the mesonephros. This may be regarded as the terminal part of the mesonephric segment of the posterior cardinal vein. In younger embryos the caudal ends of the subcardinal and caudal mesonephric vein are connected by a terminal anastomosis. Later this connection is interrupted and the two veins commence separately.

Below the junction of the caudal mesonephric vein with the main posterior cardinal vein, a vein passes upward on each side from the interiliac anastomosis, in front of the umbilical artery, and joins the pelvic or somatic part of the postcardinal vein. This is the ventral limb of the circum-umbilical venous ring, which on each side surrounds the future common iliac artery. It has probably persisted in Specimen 3, text-fig. 4, and taken the place of the dorsal limb which is formed by that part of the posterior cardinal vein which drains the caudal end of the embryo.

A reference to Plate I, fig. 4, shows that in a 12 mm. human embryo in the region which corresponds to the caudal end of the mesonephros, the primary somatic tributaries of the posterior cardinal are being transferred to a postrenal anastomosis, and in the region of the suprarenal body, Plate I, fig. 3, and at the cranial end of the mesonephros, Plate I, fig. 2, a similar transference to a more dorsally situated vein has taken place; the somatic intersegmental veins, which primarily opened directly into the postcardinal veins, now terminate in a longitudinal vein which ends in the posterior cardinal vein at the level of the 6th thoracic vertebra. The cranial end of the mesonephros and that part of the posterior cardinal vein which is contained within it soon degenerates, and the primary continuity of the upper mesonephric segment of the posterior cardinal vein is interrupted. A similar degenerative change takes place at the lower end of the mesonephros, the transverse lumbar intersegmental veins now draining into the postrenal anastomosis, which soon becomes connected by an anastomotic vein with the subcardinal vein of the corresponding side, above the level of the metanephros. The postrenal anastomosis obviously corresponds to the anastomosis behind the kidney, first

described by Hochstetter in the rabbit, which is formed by the union of the 16th with the 17th and 18th "thoracolumbar veins." It lies dorsomedial to the kidney, and below the level of the intersubcardinal anastomosis. Further, it forms with the adjoining part of the posterior cardinal vein, which lies ventrolateral to the kidney, the perinephric venous ring of Hochstetter[1]. The dorsal limb of the perinephric ring is ventrolateral to the sympathetic nerves passing from the sympathetic chain to the preaortic and hypogastric plexuses, and these nerves pass between it and the aorta. Its position relative to these nerves therefore is that of the permanent inferior vena cava, Plate II, fig. 2.

In a 19 mm. human embryo the continuity of the ventrolateral limb of the periureteric ring has become interrupted, the posterior cardinal vein in this situation having completely disappeared. The dorsomedial limb, the inferior vena cava, has on the other hand become greatly enlarged, especially on the right side. It now receives tributaries joining it on the ventral aspect from the venous plexus in front of the aorta, Plate II, fig. 2. This preaortic venous plexus receives veins coming from the mesonephros and genital gland which lie in front of or ventromedial to the ureter, and communicates also with the subcardinal veins. The postrenal vena cava on each side also receives two series of tributaries on the dorsal aspect, (1) intersegmental veins situated ventrolaterally to the sympathetic chain and rami communicantes and (2) intersegmental veins which lie dorsomedial to the sympathetic chain. The latter are joined by a discontinuous longitudinal intersegmental vein, the lumbar azygos vein, Plate II, fig. 2, which lies medial to the sympathetic chain, and ventrolateral to the lumbar arteries. The lumbar veins are also connected at this stage of development by a newly-formed longitudinal vein which is situated in front of the transverse processes of the lumbar vertebrae and behind the psoas muscle. This is the ascending lumbar vein. It is continuous above with a vein similarly situated in the thoracic region (Plate II, fig. 1). In the thoracic region at this stage longitudinal thoraco-lumbar veins which are present in an 11 mm. embryo, Plate I, fig. 1, have been replaced (19 mm. human embryo) by the permanent thoracic azygos veins, which are situated medial to the sympathetic trunk, and dorsomedial to the splanchnic nerves. In the lower thoracic region and upper part of the lumbar region the azygos veins appear to be compressed by the crura of the diaphragm and the upward current of the blood interfered with. A new channel is thus formed for the blood coming from the upper intersegmental veins in the lumbar region, by the enlargement of the corresponding part of the ascending lumbar vein; this joins the subcostal vein on each side, under cover of the medial

[1] Hochstetter describes in the rabbit a later stage in which the "perinephric" ring is succeeded by a "periureteric" ring. In the human subject and in the cat (Hochstetter), in the mole (Zumstein) and in the Mikrochiroptera (Grosser) the collateral vein lies primarily dorsomedial to the metanephros.

In the guinea-pig the "island formation" around the kidney does not take place, and in this type the metanephros migrates headwards on the ventral aspect of the posterior cardinal vein, and in *Erinaceus Europaeus* the ventral limb of the island frequently persists throughout life.

lumbocostal arch, which protects the vein from pressure. The lumbar azygos vein in this region does not as a rule entirely disappear, but persists as the small anastomotic vein which on the right side joins the dorsal aspect of the inferior vena cava, or one of its lumbar tributaries; and on the left side joins the left renal vein or a left lumbar vein. If the lumbar azygos vein becomes completely obliterated in the region of the crura of the diaphragm, the current of blood will be reversed in the lower part of the vein and flow downwards into the inferior vena cava, or on the left side into the left renal vein. Below the level of the second lumbar vertebra the lumbar azygos veins in the human embryo are not developed to the same extent as in the thoracic region, and do not as a rule form a perfectly continuous channel. Reagan and Strong have shown that they take part with the subcentral or prevertebral veins in the formation of the terminal parts of the definitive left lumbar veins. The veins of the left side being carried across the front of the vertebral column behind the aorta by anastomoses formed between the subcentral veins, a pair of longitudinal vessels, which appear about the 45 mm. stage (earlier in my specimens) and lie between the origins of the lumbar arteries. The subcentral veins thus serve as a link between the lumbar azygos veins. Reagan has also pointed out that the lumbar azygos veins are formed independently of the right and left inferior venae cavae (medial paraureteric veins) and that the azygos line is separated from the vena caval line by the branches of the sympathetic nerves, which pass from the sympathetic chain to the preaortic plexuses. The connection of the lumbar continuations of the thoracic azygos veins with the postrenal caval veins thus appears to be a secondary one. Moreover, it is evident that if the inferior vena cava is primarily developed in the azygos line, these nerves would pass both in the embryo and in the adult, superficial or ventrolateral to the inferior vena cava, instead of between this vessel and the abdominal aorta. It will be necessary here to allude to the development of the thoracolumbar veins, Plate I, fig. 1. The term "thoracolumbar" has apparently been used by some of the earlier authors to designate different vessels. Recently, however, the thoracolumbar lines have been defined by Reagan and Tribe, who describe in the rabbit a transitory pair of longitudinal veins, which arise from a plexus of capillaries situated lateral to the aorta. They extend from the midthoracic level to the sacral region. In the caudal half of the thorax these vessels are named the thoracolumbar veins. They receive the intersegmental veins, which originally drained into the mesonephric segments of the posterior cardinal veins, and convey the blood caudally into the transverse element of the inferior vena cava ("renal collar" of Huntington and McClure). They serve as temporary substitutes for the adjoining parts of the posterior cardinal veins, while these are degenerating and until the establishment of the azygos veins. For a short period the thoracolumbar and azygos veins coexist. When the azygos vessels have become functional, and once more carry the blood headward to the superior vena cava, the thoracolumbar veins disappear. Similar vessels appear to be present

in human embryos, which are of a temporary nature, and are functional between the 10 and 15 mm. stages, Plate I, fig. 1.

The lumbar segments of the longitudinal thoracolumbar lines of veins are distinguished by Reagan and Robinson as the "paraureteric veins." For a time they are symmetrical; the right, however, soon enlarges and persists as a part of the postrenal vena cava. The left eventually disappears. In the lumbar region the intersegmental veins which originally opened into the posterior cardinal veins are transferred to the paraureteric veins (or the corresponding parts of the right and left inferior venae cavae). The relation of the intersegmental tributaries of the paraureteric veins to the sympathetic trunk is a double one. Primarily they lie lateral to the sympathetic trunk and enter the paraureteric vein directly; later they pass dorsomedial to the sympathetic cord, enter the medial sympathetic vein (lumbar azygos) and by transverse communications of this with the paraureteric vein terminate indirectly in this vessel (namely, the inferior vena cava), Plate II, figs. 2, 3, 4.

A careful consideration of the different descriptions of the development of the inferior vena cava leads to the conclusion that the discrepancies are not so great as they appear, and that the account of the development of the postrenal segment of the vena cava has been rendered more difficult by different names having been applied to the same venous channels. This difficulty could be removed to a certain extent if the term inferior vena cava be applied to the main venous channel in the embryo, as soon as the definitive course is established, and the embryonic terms only used as adjectives to indicate the vessel from which a particular part of the vena cava has been derived.

An examination of a series of human embryos in my possession, ranging from 9 to 65 mm. in length, shows that large parts of the posterior cardinal and subcardinal veins degenerate completely and are replaced by a later-formed longitudinal vein or veins, and also that when once the dorsomedial limb of the periureteric ring is completed, and the anastomosis of this collateral channel with the right subcardinal is established, the main venous channel, the inferior vena cava, persists, though its position and relations become somewhat altered. It becomes more medial, and as it does so, the terminal parts of the lumbar intersegmental veins, which primarily passed ventrolateral to the sympathetic trunk, are replaced by lumbar veins the terminations of which pass dorsomedial to the sympathetic trunk. The latter veins primarily open into the lumbar azygos veins; later, by means of secondary communications of the azygos vein with the inferior vena cava, they drain permanently into the vena cava. Still later the lumbar azygos vein itself appears to become incorporated in the main channel, the inferior vena cava not being replaced by a vessel in the azygos line, but the lumbar azygos vein becoming absorbed into it, by the widening out and shortening of the communicating branches between the two longitudinal vessels, Plate II, fig. 4.

Above the level of the entrance of the two definitive renal veins into the

inferior vena cava, the right lumbar azygos vein persists as the vessel which in the adult connects the inferior vena cava with the right thoracic azygos vein, or vena azygos major. In this situation incorporation of the azygos vein into the inferior vena cava cannot take place on account of the vena cava being carried forward, and separated from the azygos vein by the right crus of the diaphragm.

Late embryos (22 mm. in length and older) show postaortic anastomoses between the right and left inferior venae cavae (supracardinal veins of Huntington and McClure) by which blood can be drawn off from the smaller left vena cava into the larger right vena cava, and the size of the left still further diminished, but there is no indication of a complete longitudinal fusion of these two vessels, like that of the right and left dorsal aortae. This possibility is negatived by the position between them of the paired origins of the lumbar intersegmental arteries (Reagan). This position of the lumbar arteries in an adult animal is exemplified by the Australian Duck Bill (*Ornithorhynchus paradoxus*). A dissection of the abdominal vessels from an adult specimen of this primitive mammal, which is figured by Hochstetter, shows the lumbar arteries passing backwards in this position between the right and left inferior venae cavae; the latter are of approximately equal size, and lie close together one on each side of the abdominal aorta, and also on each side of the origins of the lumbar intersegmental arteries. If in such an animal a direct fusion were to take place in the intervals between the lumbar arteries, then these vessels would necessarily pass right through the inferior vena cava. It is obvious that this direct fusion of the right and left inferior venae cavae does not take place n the human embryo, in which the two venae cavae are separated by a considerable interval, and a flattened remnant of the left inferior vena cava is seen for a period of two or three weeks on the left side of the aorta. In those animals in which the left inferior vena cava persists until a relatively late period of foetal life, the ultimate disappearance of the left vessel appears to be, not by direct fusion of the two veins, but by means of the anastomoses of postaortic or prevertebral tributaries, which by enlargement form wide transverse communications in the intervals between the origins of the paired lumbar arteries. The blood is thus drawn off from the left into the right vena cava, the latter vessel forming a more direct route to the heart than the left. The left vena cava consequently diminishes still further in size, and eventually its continuity opposite, and to the left of the origins of the lumbar arteries, is broken and the vein finally disappears.

Obviously that part of the inferior vena cava, which is described by Reagan as derived from the "paraureteric" vein, corresponds to the part which originates from the lumbar segment of the "supracardinal" vein of Huntington and McClure. The lumbar supracardinal veins are, however, described by the latter authors as morphologically continuous with the thoracic supracardinal veins, these latter veins being in the true azygos line, and giving rise in the human subject on the right side to a part of the vena azygos

major, and on the left side to the corresponding part of the vena azygos minor. The origin of the communicating vein (right lumbar azygos) from the posterior aspect of the inferior vena cava, and its continuity above with the thoracic azygos vein in the adult human subject, is evidence in favour of this conclusion. On the other hand, the "paraureteric" vein and the part of the inferior vena cava which is derived from it, lies ventrolateral to the nerves passing forward from the sympathetic chain to the preaortic plexuses, and thus occupies the "thoracolumbar line" and not the true "azygos line." If, however, the lower or caudal part of the lumbar azygos vein becomes incorporated in the inferior vena cava in the way suggested, this difficulty with regard to the relationship of the nerves is overcome. The inferior vena cava, which, when its course is first established, lies in the thoracolumbar line (paraureteric), incorporates or absorbs into itself the incompletely developed, often discontinuous lower part of the lumbar azygos vein, so that the main vessel in this region, from about the 8th week onward, may be regarded as composed of a large vein in the thoracolumbar line with the incorporated lower segment of the lumbar azygos vein. The nerves which pass forward from the sympathetic chain to the preaortic plexuses remain on the medial side of the inferior vena cava, and thus lie in the adult as in the embryo, between it and the aorta. If the lower segment of the lumbar azygos vein should persist in the adult, these nerves would be found between it and the inferior vena cava, and it would be continuous above with the communicating vein, which usually springs from the dorsal aspect of the inferior vena cava, and joins the thoracic azygos vein by traversing the aortic opening of the diaphragm.

It is evident that the normal position of the sympathetic nerves which in the human subject lie dorsomedial to the inferior vena cava precludes the possibility of the derivation of this part of the vena cava from an embryonic vein lying in the true azygos line. The lower, or caudal part of the "lumbar supracardinal" vein in the human subject, which gives rise to the first part of the inferior vena cava, thus according to the definition of these veins given by Reagan, lies in the thoracolumbar line, while the upper or cranial part of the "lumbar supracardinal" lies like the "thoracic supracardinal" vein in the true azygos line, since the greater and lesser splanchnic nerves lie ventrolateral to it. See text-fig. 1.

In the adult human subject a few sympathetic nerve fibres normally pass from the lower part of the lumbar sympathetic chain to the lateral part of the hypogastric plexus, in front of the common iliac vessels. This circumstance, however, does not invalidate the general conclusion that that part of the inferior vena cava which extends from near its commencement to just below the termination in it of the renal veins does not occupy the true azygos line. In the embryo, as in the adult, the principal nerves from the sympathetic chain course forward to the preaortic, mesenteric and hypogastric plexuses, medial to the inferior vena cava, and between it and the abdominal aorta, Plate II, fig. 2, a few lie lateral to the pelvic part of the posterior

cardinal vein and commencement of the umbilical artery. It is these nerves which in the adult pass in front of the common iliac vessels. If the inferior vena cava were developed in the true azygos line, it would lie dorsomedial to the principal sympathetic nerves or, in other words, these nerves, in order to reach the preaortic plexuses, would have to pass over instead of behind it.

The lower part of the left lumbar azygos vein, like that of the right side, is also incompletely developed in the human subject, and does not normally persist as a continuous longitudinal vessel. It probably takes part, however, in the transference of the left lumbar veins from their primary termination in the disappearing left inferior vena cava to the definitive right vein. The prevertebral or subcentral veins, according to Reagan and Strong, are also concerned in this temporary function.

The final course of the inferior vena cava in the human embryo appears to be determined about the 15 mm. stage, when the connection of the right supracardinal vein of Huntington with the right subcardinal vein is established. This important communicating vein is the supracardinal-subcardinal anastomosis of McClure and Butler. The general relations of the anastomosis will be realised by reference to Plate II, fig. 3, which represents a transverse section of a 22 mm. human embryo. It will be noted that the right side has become enlarged so as to form the main venous channel, the "pars renalis" of the inferior vena cava, whereas the left side of the "renal collar" has already narrowed prior to its disappearance at a later stage.

The embryonic veins which take part in the formation of the inferior vena cava thus comprise:

(1) The *right supracardinal* (right paraureteric vein). This is a longitudinal axial vein in the thoracolumbar line, which is continuous caudally with the pelvic (somatic) part of the right posterior cardinal vein. It connects the lumbar intersegmental veins, and is situated between two series of sympathetic nerves: (*a*) nerves which lie lateral to the main venous channel (inferior vena cava) and pass in a dorsoventral direction from the sympathetic cord to the suprarenal and renal plexuses, and the lateral part of the hypogastric plexus; (*b*) nerves which are situated medial to the main vein (inferior vena cava) and pass in a dorsoventral direction from the sympathetic chain to the preaortic plexus and its derivatives, viz. the superior mesenteric, genital, and inferior mesenteric plexuses, and the central part of the hypogastric plexus (Plate II, figs. 3, 4). In the human subject the lower part of the right lumbar azygos vein appears to be incorporated into the main channel. This conception of the absorption of the lower part of the right lumbar azygos vein into the main venous channel is supported by the fact that the upper part of the right lumbar azygos vein in embryos above 20 mm. in length, and in the adult, springs from the dorsal aspect of the inferior vena cava.

(2) The supracardinal-subcardinal anastomosis.

(3) A part of the right subcardinal.

(4) The anastomosis of the right subcardinal vein with the common hepatic vein by means of the hepatic sinusoids.

(5) The common hepatic vein.

EXPLANATION OF ANOMALIES

The explanation of the main features of the anomalous venae cavae described in this article are briefly as follows:

Specimens 1 *and* 2. Persistence on the left side of the corresponding embryonic veins, which normally give origin to the postrenal part of the right inferior vena cava, namely, the left supracardinal vein; the anastomosis of this with the left subcardinal vein; a part of the left subcardinal vein, and the intersubcardinal anastomosis, which joins the left with the right inferior vena cava.

Specimen 3. Persistence of the ventral limb of the circum-umbilical venous ring, and disappearance of its dorsal limb.

Specimen 4. Persistence of the whole of the postrenal segment of the left subcardinal vein.

Specimen 5. Persistence and enlargement of postaortic anastomoses between the embryonic inferior venae cavae, and of one of the primary left renal veins.

The accessory renal artery and accessory renal veins in Specimen 4 are due to the persistence of primary embryonic renal vessels. These temporary or primary embryonic arteries and veins frequently penetrate or emerge from the medial aspect of the metanephros instead of traversing the hilum, which in the early stages of development is directed ventrally and thus does not afford a direct line of entrance or exit for the vessels. The primary embryonic arteries supplying the right kidney usually pass ventral to the inferior vena cava, and between it and the subcardinal vein. One of these vessels has persisted in Specimen 4.

The tributary vein which joins the inferior polar vein of the right kidney in Specimen 4 is probably due to a persistence of one of the numerous veins which in the embryo drain the degenerating mesonephros. In early embryos when the kidney is low in position these vessels lie ventral to the metanephros; when the kidney has ascended into the lumbar position, the vessels are left in a subperitoneal position on the posterior abdominal wall below the level of the kidney.

A knowledge of the percentage frequency of a large vein situated on the left side of the abdominal aorta is of some surgical importance in connection with operations such as the Hunter-Royle method of treating spastic paralysis of the lower limbs by "lumbar sympathetic ramisection." The abnormal vein may be due either to double inferior vena cava, or a single left inferior vena cava. The latter may occur in transposition of the viscera, or may be due to persistence on the left side of the embryonic veins corresponding to

those which normally give origin to the postrenal segment of the inferior vena cava on the right side.

The statistical material of which I have had personal knowledge is that which has come under my observation in the Anatomy Departments of the Middlesex Hospital Medical College and King's College, London; and I am indebted to Prof. T. Yeates for the information with regard to the average number of subjects which have been used in the Anatomy Department of the Middlesex Hospital since his period of office in that Institution, during which no case of double or left inferior vena cava has occurred. I am thus enabled to add the number of subjects which have been dissected in the Department during this latter period to those which came under my observation in the same Institution beforehand. The total number of cases during the two periods is approximately 500, during which time one case of a large left inferior vena cava occurred, and no instance of a double inferior vena cava. During the period 1912 to 1928, in which I have been teaching in the Anatomy Department of King's College, London, the number of subjects which have been dissected is 376, and two examples of bilateral postrenal vena cava have occurred.

The total number of cases examined and those in which a large vein is present on the left side of the abdominal aorta, including Specimen 4, is respectively:

Middlesex Hospital	500	1
King's College, London	376	3
	876	4

These figures, which must be regarded as approximate only, give the percentage frequency of a large vein ascending on the left side of the abdominal aorta as 0·45. Double inferior vena cava appears to be about twice as frequent as single left inferior vena cava; a conclusion which is supported by a comparison of the figures given above with the proportional number of cases of each variety which have been published, and have been classified by Maxwell and Erwin (16) and by Wicke (25).

In conclusion I wish to express my high appreciation and indebtedness to the authors whose names I have included in the appended bibliography, and more especially to the works of Hochstetter, McClure and Butler. I wish to thank Prof. Blair, Dr Reagan and Miss Tribe for their valuable personal help.

I also wish to thank Mr Mitchell Smith, Mr Sourasky, Mr Glazebrook, Mr Hollenrake and Mr Kemp for help given in dissection and drawing of the specimens, and I further wish specially to acknowledge my indebtedness to the excellent work of Mr J. Weston, who has prepared most of my serial sections of human embryos.

EXPLANATION OF PLATES I AND II

Plate I

Fig. 1. Transverse section through an 11 mm. human embryo, showing the positions of the posterior cardinal, thoracolumbar, and azygos lines of veins relative to the sympathetic cord and splanchnic nerves.

Ao. Aorta.
AzLV. Small veins situated in the future azygos lines.
MN. Mesonephros.
PCV. Posterior cardinal vein.
PrCV. Precostal vein.
S. Sympathetic ganglion.
SMA. Superior mesenteric artery.
SN. Sympathetic nerve.
SR. Suprarenal gland.
ThLV. Thoracolumbar veins.

Fig. 2. Sagittal section of a 12 mm. human embryo to the right of the median plane, showing the junction of the temporary thoracolumbar vein with the posterior cardinal vein at the level of the body of the 6th thoracic vertebra.

CHV. Common hepatic vein.
L. Liver.
MN. Mesonephros.
PC. Posterior cardinal vein.
PPO. Pleuroperitoneal opening.
RL. Right lung.
ThLV. Thoracolumbar vein. This vein will be replaced about the 15 mm. stage by a vessel in the azygos line, viz. the thoracic azygos vein, or thoracic supracardinal vein of Huntington and McClure.

Fig. 3. Sagittal section of a 12 mm. human embryo to the right of the median plane, showing an anastomotic vein joining the posterior cardinal vein with the thoracolumbar vein, at the level of the suprarenal body.

AnV. Anastomosing vein.
GG. Genital gland.
HS. Hepatic sinusoids.
ISV. Intersegmental veins.
IVC. Inferior vena cava.
L. Liver.
MN. Mesonephros.
PCV. Posterior cardinal vein.
RL. Right lung.
SR. Suprarenal gland.
ThLV. Thoracolumbar vein.

Fig. 4. Sagittal section of a 12 mm. human embryo passing to the left of the median plane. It shows the termination in the left posterior cardinal vein of a tributary coming from the postrenal anastomosis, and coursing forward above the upper pole of the kidney. A similar but much larger vein is present on the right side. These vessels, and the longitudinal postrenal anastomosis, represent the posterior limb of the perinephric ring of Hochstetter. Note also the opening of the lumbar intersegmental veins into the postrenal anastomosis, and the relation of the latter and the kidney to the left common iliac artery.

AnV. Anastomotic vein, which probably represents the primary termination of a lumbar intersegmental vein in the posterior cardinal vein.
ISV. Intersegmental veins.
K. Metanephros.
LCIlA. Commencement of umbilical artery.
P. Pancreas.
PCV. Posterior cardinal vein.
St. Stomach.
WB. Mesonephros.
UA. Umbilical artery.

Plate II

Fig. 1. Transverse section through a 19 mm. human embryo, showing the relations of the thoracic azygos veins, and precostal veins to the sympathetic cord, greater and lesser splanchnic nerves and rami communicantes. The extent of the lateral displacement of the cranial end of the mesonephros at this stage is indicated by the position of the "coronary appendage" of the liver. The upper pole of the mesonephros lies just below this structure.

Ao. Thoracic aorta.
CAp. Coronary appendage of liver.
C.X. Tenth rib.
DV. Ductus venosus.
IVC. Inferior vena cava (pars hepatica).
GS. Ganglion of sympathetic chain.
L. Liver.
NSp. Splanchnic nerves.
NV. Right and left vagus nerves.
PrCV. Precostal vein.
SR. Suprarenal gland.
St. Stomach.
TAzV. Thoracic azygos veins.
VTh.X. Tenth thoracic vertebra.

Fig. 2. Transverse section through a 19 mm. human embryo, passing through the abdominal aorta just above its bifurcation. The section shows a large vein entering the inferior vena cava on its ventral aspect. This vessel forms the ventral limb of the circum-umbilical ring round the origin of the right common iliac artery. Lumbar intersegmental veins pass forward to the inferior vena cava on each side of the sympathetic chain. The axial veins situated on the median side of the sympathetic chain and between the sympathetic nerves and lumbar arteries are the lumbar azygos veins. The inferior venae cavae lie lateral to the sympathetic nerves passing forward to the hypogastric plexus, and medial to the ureters.

ALV.	Ascending lumbar vein.	*PGP.*	Preaortic plexus of veins terminating above in the subcardinal veins.
GG.	Genital gland.	*RC.*	Ramus communicans.
LA.	Lumbar intersegmental arteries.	*RIVC.*	Right inferior vena cava (pars supracardinalis).
LIVC.	Left inferior vena cava (pars supracardinalis).	*RK.*	Right kidney.
LLAzV.	Left lumbar azygos vein.	*SN.*	Sympathetic nerve.
LV.	Lumbar vein.	*ST.*	Sympathetic trunk.
MN.	Mesonephros.	*U.*	Ureter.

Fig. 3. Transverse section through a 22 mm. human embryo at the level of the supracardino-subcardinal anastomosis. On the left side the anastomosing vessel has become constricted, prior to its disappearance at a later stage. The relation of the principal veins to the sympathetic chain and to the preaortic and renal ganglia is shown; and also the relation of the lumbar intersegmental veins and subcentral vein to the lumbar arteries. The termination of the internal spermatic veins in the subcardinal veins is also indicated.

Ao.	Abdominal aorta.	*LV.*	Lumbar intersegmental veins.
K.	Kidney.	*PAoG.*	Preaortic ganglia.
LA.	Lumbar intersegmental artery.	*RISpV.*	Right internal spermatic vein.
LISpV.	Left internal spermatic vein.	*RSV.*	Right subcardinal vein.
LRG.	Left renal ganglion.	*RSpV.*	Right supracardinal vein.
LSV.	Left subcardinal vein.	*SG.*	Ganglion of sympathetic chain.
LSpV.	Left supracardinal vein.	*Sp-SCAn.*	Supra-subcardinal anastomosis.

Fig. 4. Transverse section through a 22 mm. human embryo below the intersubcardinal anastomosis, showing the relation of the lumbar azygos veins to the inferior venae cavae. On the right side the lumbar azygos vein is connected to the inferior vena cava by a communicating branch. It is probable that the lower parts of the lumbar azygos veins become incorporated in the inferior vena cava by the widening out of these communications. The azygos veins lie medial to the sympathetic chain, and ventrolateral to the lumbar arteries.

Ao.	Abdominal aorta.	*LLV.*	Left lumbar intersegmental vein.
CSG.	Collateral sympathetic ganglia (renal).	*RISV.*	Right internal spermatic vein.
GG.	Genital gland.	*RIVC.*	Right supracardinal vein.
ISA.	Internal spermatic artery.	*RK.*	Right kidney.
LA.	Lumbar artery.	*RLV.*	Right lumbar vein.
LISV.	Left internal spermatic vein.	*SCV.*	Right subcardinal vein.
LIVC.	Left supracardinal vein.	*SG.*	Ganglion of sympathetic chain.
LK.	Left kidney.	*U.*	Ureter.
LLAzV.	Left lumbar azygos vein.		

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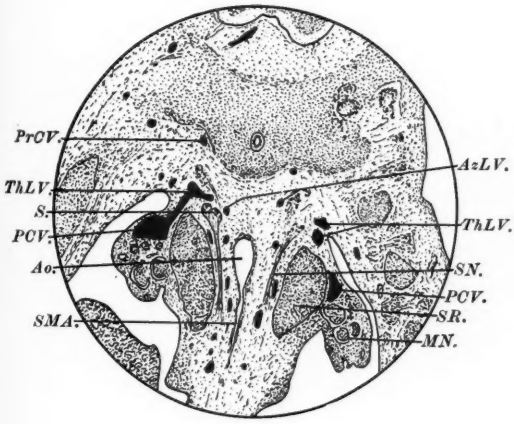

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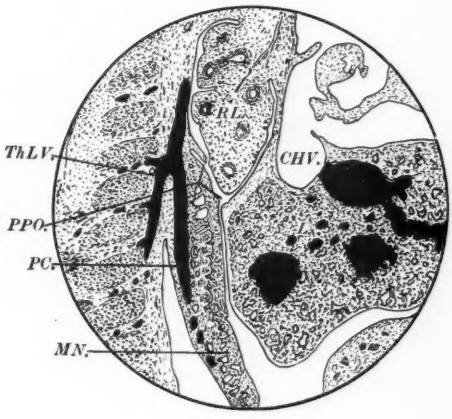

Fig. 2

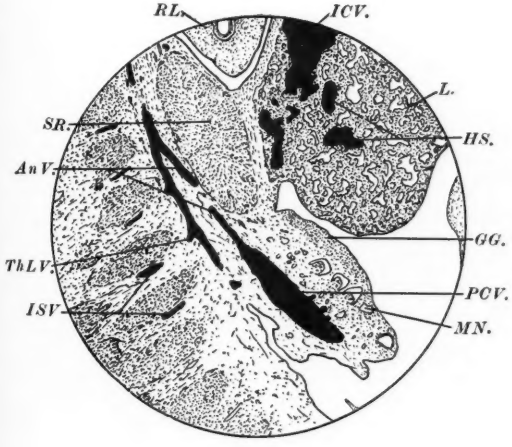

Fig. 3

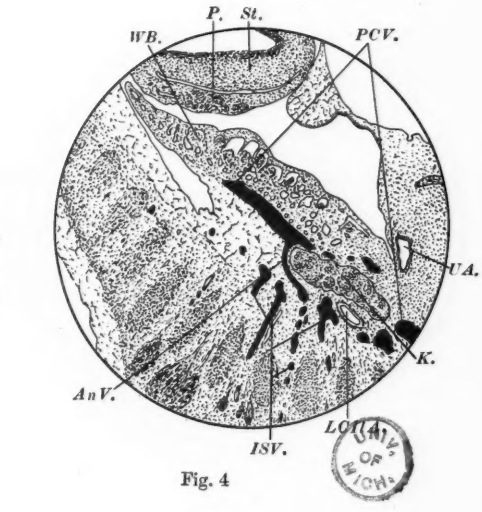

Fig. 4

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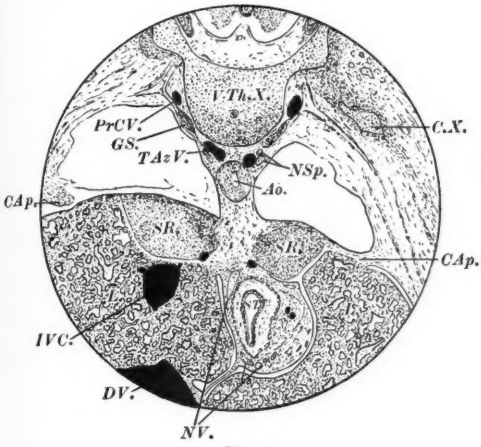

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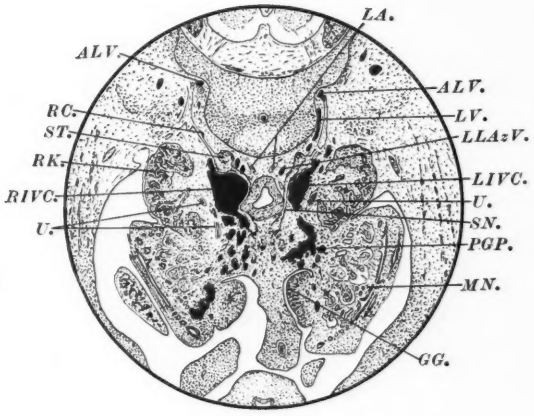

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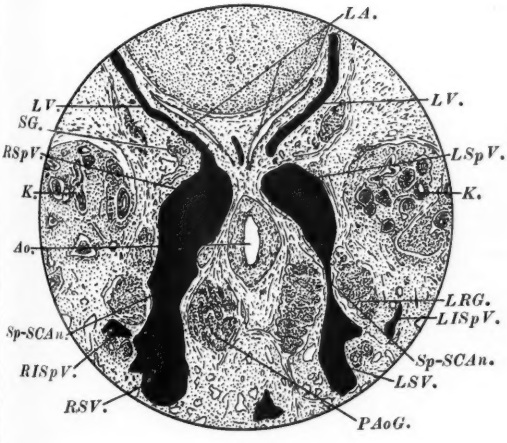

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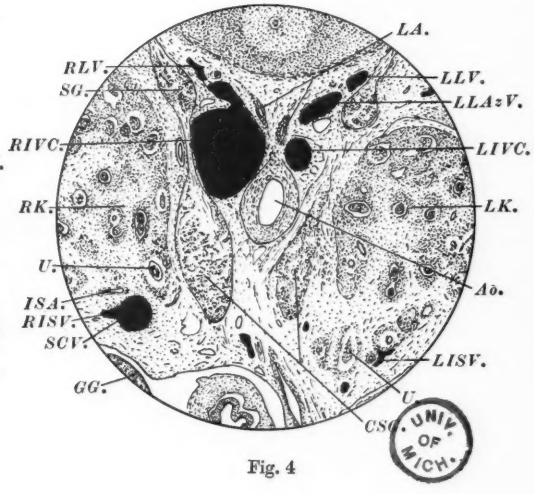

Fig. 4

UNIV. OF MICH.

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ABERRANT ACCESSORY URETER ASSOCIATED WITH HYDRONEPHROSIS

By HAROLD EDWARDS, M.S., F.R.C.S.
Junior Surgeon and Surgical Tutor, King's College Hospital

The specimen consists of the whole urinary tract of a female child with the exception of the distal portion of the urethra. On the right side is a normal kidney, with a single ureter opening into the bladder in the usual manner. On the left side, the kidney is composed of two distinct portions, each possessing a separate pelvis and ureter. The lower portion appears to be anatomically normal and the corresponding ureter is also normal, both in appearance and in the manner in which it opens into the bladder. The upper portion of the kidney is dilated, with the calyces almost completely obliterated, and the renal substance forming a layer ¼ in. in thickness. The pelvis shares in this dilatation, but the most marked change has occurred in the ureter. This is dilated and extremely tortuous. It passes behind the other ureter on this side to open into the commencement of the urethra, the opening lying below and internal to the opening of the first ureter (see fig. 1).

There are numerous miliary abscesses throughout the substance of both kidneys.

The specimen is of interest from both embryological and clinical standpoints.

Ureters opening in an abnormal situation are nearly always supernumerary, though eight cases have been reported in which the truant ureter was single. The great majority of 66 cases recently summarised by Campbell Begg[1] occurred in the female, and of these 75 per cent. opened into the vagina, and 24 per cent. into the urethra.

Formerly it was held that the bladder, with the exception of the trigone, arose from the allantois. The work of Felix, quoted by the above author, appears to have established that the upper part of the bladder and the urachus are derived from the ventral cloaca, while the trigone, urethra and vestibule are for the most part Wolffian in origin. The various anomalies of situation for the ureteric orifices referred to above lends support to this view. The anomalies cannot, in fact, be explained on any other supposition.

The renal bud which forms the excretory portion of the kidney arises from the lower end of the Wolffian duct, which at this stage is becoming funnel-shaped and fusing posteriorly with its fellow of the opposite side to form the base of the bladder. Descent of the Wolffian duct now occurs, so that the ureteric orifice comes to lie above that part of the duct which is

[1] R. Campbell Begg, *British Journal of Surgery*, vol. xv, 1927, p. 229.

destined to form the vas deferens in the male, or the duct of Gaertner in the female. If a second ureteric bud now appears on the same side, it will be at a higher level along the Wolffian duct than the first bud, and will therefore be covered by the cephalic portion of the metanephric cap, corresponding with the upper half of the kidney. As the lower end of the Wolffian duct has descended to a point below the opening of the first ureteric bud into what now

Fig. 1. The white rod demonstrates the orifice of the aberrant ureter

constitutes the trigone, this accessory ureter must open into the lower urinary tract at a lower level than its companion. It is a fact well recognised among cystoscopists that the lower opening of a double ureter always corresponds to the upper half of the kidney to which they both belong. The position of the opening of the accessory ureter depends entirely upon the point of time at which the second bud is developed. If it arises at a short interval after the first one, then it will open into the bladder just below and median to the latter. If at a much later stage of development it may actually open

outside the bladder—into the urethra, or into the vagina or vaginal vestibule, or even into a patent duct of Gaertner. In the male it may open into the ejaculatory duct or the seminal vesicle.

The clinical significance of the condition is twofold. Firstly in the great tendency of the portion of the kidney drained by the aberrant ureter to hydro-nephrosis and subsequent infection, and secondly in that the condition may be a cause of obscure incontinence of urine in women.

Why hydro-nephrosis and hydro-ureter should result is not clear. A probe has been passed through the ureteric orifice (see fig. 1), so that there is no definite stricture present. Obstruction may be caused through a fold of mucous membrane in the lower end of the ureter, but the constant dribbling incontinence which is the clinical feature of the condition, does not uphold such a supposition. Poynton and Sheldon[1] found an organic cause for dilatation of a single, normally placed ureter in the cases of that type available for examination. They express the view that, although some cases occur in which no definite obstructing factor can be demonstrated, in the majority of cases an organic obstruction can be found if diligently sought.

There remain a number of cases, however, in which no obstruction can be found on post-mortem examination, though the condition is exactly what one would expect to result from obstruction to the outflow of urine from the ureteric orifice during life. No difference in macroscopic appearances can be detected between the cases where organic obstruction is present and those where it is absent in post-mortem examination. In the latter cases, obstruction ceases with death. The nature of such obstruction must be muscular—constant or intermittent spasm of the muscle surrounding the orifice of the ureter. The cause of such a condition lies in the lack of co-ordination between nerve and muscle at the point of entry of the ureter through the bladder wall.

We are ignorant of any relation between neuro-muscular disfunction and congenital defects in stricture. Poynton and Sheldon mention three examples of horse-shoe kidney associated with dilatation of ureters, but recognise no direct relation between horse-shoe kidney and stenosis of the ureter.

The very high incidence of dilatation in aberrant ureters suggests that the dilatation is very closely related to the developmental anomaly, if not wholly dependent upon it. A structural defect calculated to produce permanent upset of nerve and muscle action would most readily occur in situations where development from the embryo has already shown an anomaly.

[1] Poynton and Sheldon, *Arch. Dis. in Child.* vol. II, 1927, no. 11, p. 251.

ANATOMICAL NOTES

COMPLETE ABSENCE OF THE QUADRATUS FEMORIS

By E. P. STIBBE

Absence of the quadratus femoris is described as occurring in 1 per cent. of subjects. It would seem actually to be considerably less common than this, at least so far as exchange of ideas with one's colleagues furnishes a criterion. Moreover, in most cases of so-called absence of this muscle there is some representative of it in the form of excessively large inferior gemellus, or of upward extension of an the adductor magnus into the region usually occupied by the quadratus femoris.

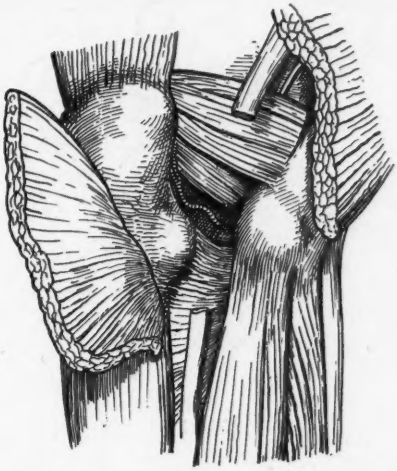

Fig. 1

The case illustrated is a case of genuine absence in the left extremity of an aged male adult. The inferior gemellus is normal in size and the upper border of the adductor magnus shows the characteristic concavity, the upper limit of which is the lesser trochanter of the femur.

The nerve to the quadratus femoris occupies its usual position under the great sciatic nerve; it is very much reduced in size, and divides under the obturator internus into two branches—one of which goes to supply the inferior gemellus, while the other ends in the back of the capsule of the hip-joint.

No other muscular anomalies were found in the subject.

A BURSAL SAC IN THE SUBSTANCE OF THE SUBSCAPULARIS

By E. P. STIBBE

The sac shown *in situ* in figure was found in a male subject aged 60 in the dissecting-room of University College, London. It is embedded in the substance of the muscular part of the subscapularis near to the tendon of insertion. It is one and a quarter inches in length and half an inch in greatest diameter, tapering somewhat at its inner end; its long axis lies in the direction of the fibres of the muscle. It is separated by a definite plane of cleavage from the muscle, the fibres of which can readily and completely be pushed aside from it without any dissection.

Fig. 1

Contents. Glairy thick fluid like raw white of egg—just such as one would expect to find in a bursa. Wall thick and rigid in the part near the shoulder-joint, thinner in the distal part of the sac.

Microscopy. Wall made up of parallel bundles of white fibrous tissue. Cavity lined up by an imperfect small-celled endothelium. Differential staining shows no cartilage in the wall. The cavity of the sac does not communicate with the shoulder-joint. Under the subscapularis is the normal subscapularis bursa, communicating with the joint.

Diagnosis

The cyst is non-inflammatory since it is perfectly unattached. It is unlikely to be parasitic, since no other anomalies were found in the subject. Against its being a baker's cyst is the fact that the shoulder joint is absolutely normal; moreover it does not communicate with the joint, though this is not a necessary condition of the diagnosis.

We appear to be left with the possibility of the cyst being of the nature of an adventitious bursa only; but we are at a loss to explain the condition.

COMITÉ INTERNATIONAL DES RECHERCHES DES PARTIES MOLLES (PARTIES NON OSSEUSES)

By SIR ARTHUR KEITH

For the advance of any branch of knowledge international co-operation is necessary. This is more true of some subjects than of others; it is absolutely essential if we are to come by a knowledge of the Anatomy of Human Races—which, for convenience, may be named Racial Anatomy. In the anatomical literature of all countries are to be found stray records of dissections made on the less common races of mankind and from such records it may be inferred that each race of mankind, as is true of each species of the higher Primates—has its own particular range of structural variation. Racial anatomy—which deals with groups of individuals—has made little or no progress hitherto and the reasons are very apparent. These are, in the first place, the labour and expense involved. The complete dissection of a human body involves months of labour; to make a complete record of what is seen and found requires continued application; the publication of such records is costly. Such investigations require, on the part of the anatomist, a spirit of altruism for at the most all he can hope for is that his labour may form a brick in the ultimate edifice which will take centuries to erect. There is the further difficulty of obtaining the requisite material. Only on rare occasion do we come by an opportunity of dissecting the bodies of Bushmen, Andaman Islanders or Australian aborigines or the rarer Anthropoids; lack of opportunity is the least of the difficulties which stand in the way of advance. The real difficulty is to obtain an international collective effort.

For many years Prof. Edward Loth, of Warsaw, has realised that if Racial Anatomy is to advance, international co-operation must be obtained. Prof. Loth came to London in 1927 when the members of the Association des Anatomistes and of the Anatomical Society of Great Britain met at University College, London, under the presidency of Prof. Brachet and of Prof. Elliot Smith. He advocated the formation of an international Committee to encourage and supervise the collection of data relating to the racial anatomy of mankind—in particular the anatomy of the soft parts of the body. At his instigation an international Committee was formed of which Prof. Anthony of Paris and the writer were appointed members, Prof. Loth himself undertaking all secretarial duties. The Committee was empowered to approach anatomists of all countries, entreat their co-operation and invite representatives to join them so that its constitution would become truly international. Since the London meeting Prof. Loth has pushed this international scheme forwards with great vigour and success. The title of the Committee—"Comité

International des Recherches des Parties molles"—he has wisely contracted to a more practical form—"C.I.R.P."—an abbreviation which will be appreciated by all concerned.

Prof. Loth has the affairs of the C.I.R.P. much at heart and has lost no opportunity of advancing its cause. He has approached the "International Institute for Intellectual Co-operation" and the president of that Institute—which is a child of the League of Nations—has promised him support for C.I.R.P. With the help of Prof. Anthony steps were taken to bring the objects of C.I.R.P. to the notice of members of the medical services of the Colonial government of France. Prof. Loth approached the anatomists of Portugal and obtained their aid in bringing the objects of the C.I.R.P. to the notices of their medical colleagues stationed in Portuguese colonies and in Brazil. He is naturally desirous, and in this he has the unanimous support of his colleagues, that British anatomists should become participators in this international effort. They have wider and better opportunities of obtaining material for investigation than are given to most of their colleagues of other countries.

If racial or collective anatomy is to prosper the C.I.R.P. must bring the material to those who are willing to investigate it. The needs of racial anatomists must be made known to medical men practising in the backward regions of all parts of the world. The material has to be collected and conveyed to certain centres for preservation and distribution. Anatomists who wish to make investigations must make their needs known to the C.I.R.P. Upon the C.I.R.P. will fall the organisation of three voluntary services: (1) to collect material; (2) to preserve it at convenient centres; (3) to distribute it as required. There remains to be discussed the problem of publication of prepared records of dissections.

Prof. Loth has already received reports of dissections made by Prof. Pires de Lima of Porto and by Prof. Leblanc of Algeria (on forty Berbers).

There remains another matter—an important one—which requires the serious consideration of anatomists in all countries. Hitherto all expenses have been defrayed by the Secretary of C.I.R.P.—or by his department. This cannot continue; a fund will have to be raised sufficient to cover cost of correspondence and printing and all expenses involved in transport and storage of material. Prof. Loth begs that secretaries of Anatomical Societies in all countries will bring the proposals of the C.I.R.P. before their administrative councils and hopes that financial support may be forthcoming. He hopes, too, that assistance may be obtained from funds which have been bequeathed or assigned for the advancement of scientific enquiries of an international character.

The writer of this notice would urge that anatomists who are in sympathy with the objects for which C.I.R.P. has come into existence will communicate with Prof. E. Loth (5 Chalubinski, Warsaw) and inform him: (1) of their wish to participate in the work of the Committee either as collectors or dissectors; (2) that they will state what material they need for any research they may

have in hand or propose to make; (3) any point in racial anatomy which they regard as being urgently in need of investigation.

The Committee as constituted at present must be regarded as merely temporary; its final constitution and membership will be determined as soon as its international character is assured.

Prof. Loth has prepared for the consideration of the Committee (1) a programme of investigations which are most urgently needed; (2) suggestions as to the best means of preserving material for dissection and examination; (3) suggestions for its transport and distribution. These will be considered and it is hoped will be adopted and circulated.

He has also drawn up the following list to exemplify the points of structure in various regions of the body which require extended observation:

HEAD:

(1) Is the Risorius of Santorini present?
(2) Is the *m. transversus menti* present or not?
(3) Is the *m. transversus nuchae* present?
(4) Is there a separate *m. epicranius parieto-temporalis*?
(5) Is the *m. auricularis posterior* unigastric, digastric or polygastric?

NECK:

(1) To note the presence or absence of tendinous inscriptions in the infra-hyoid muscles.
(2) To note the frequency of insertion of the *m. sternohyoideus* to sternum, clavicle, first, second, third or fourth ribs.

TRUNK:

(1) Is a *m. sternalis* present?
(2) Does the *m. pectoralis major* possess a *pars abdominalis*?
(3) The series of ribs to which the *m. serratus anterior* is attached.
(4) The number and position of tendinous inscriptions in the *m. rectus abdominis*.
(5) The members of the costal series which give origin to the *m. rectus abdominis*.
(6) The members of the costal series which give origin to the *m. obliquus externus*.
(7) The members of the costal series which give origin to the *m. obliquus internus*.
(8) The members of the costal series which give origin to the *m. transversus abdominis*.
(9) Does the *m. pyramidalis* exist or not?

BACK:

(1) Note the last (lowest) spinal insertion of the *m. trapezius*.
(2) Record the spinous processes to which the *m. latissimus dorsi* is attached.
(3) Record the costal attachments of the *m. latissimus dorsi*.
(4) Is the *m. dorso-epitrochlearis* present? If so, record its degree of development and attachments.
(5) Name the transverse processes which give attachment to the *m. levator scapulae*.
(6) Note the series of spinous processes which give origin to the *m. splenius*.

ARM:

(1) Has the *m. biceps brachii* supernumerary heads? If so state their number and their attachments.
(2) Does the *m. pronator teres* possess a coronoid head?

(3) Is there a *m. palmaris longus*? What is its state?

(4) Record the following points in connection with the termination of the *m. extensor pollicis brevis*: (*a*) if to distal phalanx only; (*b*) if to proximal phalanx only; (*c*) if to both phalanges.

(5) Make similar records regarding the *m. pollicis longus*: also note if it receives a reinforcement on the distal phalanx from the *m. pollicis brevis*.

(6) The following points should be noted regarding the *m. lumbricales*: (*a*) their number and arrangement; (*b*) the exact insertion of each, particularly those ending on the third and fourth digits.

LOWER EXTREMITY:

(1) Does *m. psoas minor* exist or not?

(2) Does *m. pyriformis* exist or not?

(3) Which of the two parts—the medial or lateral—of the *m. gastrocnemius* descends the lower?

(4) Does *m. plantaris* exist or not?

(5) Name the tendons for the toes from the *m. flexor hall. long.*

(6) Name the tendons for the toes from the *m. flexor digit. long.*

(7) Does *m. peroneus tertius* exist or not?

(8) Does the tendon for the fifth toe of the *m. flexor digit. brevis* exist or not?

VISCERA:

(1) The palate: number of the palatine ridges.

(2) The tongue: position of the *papilles calciformes* percentage V, percentage Y, percentage T.

(3) Intestines: length of the small and great intestine.

(4) Appendix: position and length.

(5) Is the *diverticulum Meckeli* present or not?

(6) Liver: weight of the healthy liver.

(7) Spleen: weight of the healthy spleen.

(8) Nose: number of the nasal conchae.

(9) Larynx: (*a*) ossification of the cartilages according to age; (*b*) are the opposite *m. cricothyreoidei* separated or joined in the middle line? (*c*) size of the *ventriculus laryngis*.

(10) Lungs: supernumerary lobes on the right and left.

(11) *Gland. thyreoidea*: weight of the healthy gland.

(12) Kidneys: the form of the *pelvis renalis*.

ANGEIOLOGY:

(1) Heart: weight.

(2) Aorta: (*a*) *truncus brachiocephalicus bicarotideus* percentage, type normal percentage, the vertebral artery directly from the aorta percentage, subclavian artery directly from the aorta percentage, thyreoidean artery directly from the aorta percentage; (*b*) does the *art. laryngea* perforate the thyreoidean cartilage? (*c*) does the *art. mediana* exist or not? (*d*) does the *art. obturatoria* (corona mortis) exist or not?

Prof. Loth gives the following tabulated observations on two muscles (*m. risorius* and *m. palmaris longus*) to illustrate the kind of result which may be attained and greatly extended, by collective observation. Only by an international effort can the scattered records already published be brought into a system and to attain the objects which the C.I.R.P. has in view, the

effort must not only be international but must be continued by many generations of anatomists.

Specimen of Tabulated Results.

Question	Author	Laboratory	Race of the subjects examined	Number of observations	%
Muscle Risorius Santorini exist	Harslem Riemschneider	Freiburg	Melanesians	28	14
	Kudo	Niigata	Chinese	12	83
	Koster	Rotterdam	Malayans	10	10
	Burkitt	Adelaide	Australians	1	?
	Roquette, Pinto	Rio de Janeiro	Maneteri (Brazil)	1	?
Palmaris longus absent	Nakano	Peking	Chinese	95	2·2
	Thomson, Batts, etc.		Negroes (American)	636	4·8
	Roquette, Pinto	Rio de Janeiro	Maneteri (Brazil)	1	?

ERRATUM.

Vol. LXIII, Part III, April 1929, p. 305, Fig. 3. "Mitral valve" and "tricuspid valve" *transpose*.

REVIEWS

Taschenbuch der Pathologischen Anatomie. By Prof. Dr Med. E. von GIERKE. 10th edition, 1929. Vol. I, 5 marks; vol. II, 6.50 marks. (Georg Thieme, Leipzig.)

Professor von Gierke's "Pocket Pathological Anatomy" is written with the express object of relieving students from the necessity of taking lecture-notes, and as a substitute for them. He holds the view, with which most teachers will agree, that the practice of taking notes during the delivery of a lecture almost entirely deprives the latter of its value, and should be discouraged. The lecture becomes in fact little more than a lesson in dictation. The volumes may be recommended as being somewhat different from what are known as Students' Aids; it is virtually a carefully prepared and skilful abstract, by an expert teacher, of the substance of his course of lectures, and doubtless will be found useful to students in following the lectures. It therefore has the novel feature of being a companion to the lecture-room. It is evidently very popular among students in Germany, and deservedly so.

Anatomy and the Problem of Behaviour. (Lectures delivered at University College, London.) By G. E. COGHILL. (Cambridge University Press.) 1929. Pp. x + 113. 52 Figs. Price 7*s.* 6*d.* net.

In *Anatomy and the Problem of Behaviour*, Prof. Coghill, of the Wistar Institute, Philadelphia, has gathered together into these three stimulating lectures the results of his studies on the development of the nervous system of the larva of *Amblystoma*. The period of development falls into five physiological stages, ranging from the non-motile stage, through the early flexure stage when the animal first responds to light touch on the skin, the coil stage and the "S" stage to the early swimming stage. The histology of the nervous system is clearly described and the changes in complexity, proliferation and differentiation are traced with a view to elucidating the problems of behaviour as determined by actual experiment. The motor response of the larva has been recorded by the cinematograph, and the reflexes of the fore-limb, hind-limb, gills and the feeding reaction have been studied in detail.

The manner in which the behaviour pattern expands by the addition of local patterns for the fore-limb, hind-limb and gills to the dominant pattern for the trunk affords a picture of co-ordination which in its concept is as fundamental as Sherrington's integrative action of the central nervous system. The dynamics of the developing neural mechanism is interpreted in terms of gradients of growth and differentiation, and the precocity of the

neural development is clearly portrayed. The pattern of the nervous system is laid down in a definite anatomical structure before nervous function, excitation or exercise begins, and also before vascularisation of the nervous system occurs. Thus the development growth and exercise of the limb muscles cannot be responsible for the neural pattern of the fore-limb. The growing animal is not the sum of its reflexes. At any moment it has a potential nervous behaviour pattern far ahead of its actual physical performances. The demonstration of Bateson's "all-pervading orderliness" is outstripped by Coghill's proof of the precocious, ever-ready and all-pervading orderliness of the nervous system.

In the application of his results to "Gestalt," the extent to which habit is independent of the development of the cerebral cortex, is discussed in such a manner as to indicate a new and fruitful method of approach to a sane psychology. The "psyche" of the young *Amblystoma* is better known than that of any other animal form.

Anatomical Society of Great Britain and Ireland

PROCEEDINGS

November, 1928 *February*, 1929
May, 1929 *June*, 1929

RECORDED BY
R. J. GLADSTONE

EDITED BY
E. BARCLAY-SMITH

PROCEEDINGS OF THE ANATOMICAL SOCIETY OF GREAT BRITAIN AND IRELAND

THE Annual Meeting of the Anatomical Society was held in King's College, London, on Friday, November 23rd, 1928. In the absence of the President the chair was first taken by Professor T. B. Johnston and later by Professor W. Wright.

Mr J. H. MULLIGAN read a paper on "Complete absence of the corpus callosum in a human brain." This has been submitted for publication in the *Journal of Anatomy*.

In the discussion which followed Professor LE GROS CLARK alluded to the experiments of Pawlow on the corpus callosum, stating that section of the corpus callosum was followed by no definite changes; and that in a case of accidental division of the corpus callosum, in an operation upon a boy with hydrocephalus, there was no change in his mental condition.

Professor WRIGHT commented on the remarkable way in which the functions of the brain could be carried out in the absence of so large a commissure.

Professor C. J. PATTEN gave a demonstration of the "technique of bird utterances," this being an expansion of the communication which he made at a previous meeting at which he exhibited a model of the vocal apparatus of the bird.

He exhibited a very much enlarged model, which he had designed, of the syrinx of a typical song-bird. He explained that while the production of voice-sounds may originate as far down as the bifurcation of the trachea, the latter, in its entire length, plays a major part in the mechanism of voice-production. The mechanical action of the wind-pipe aided materially in giving resilience and mellowness to the tone of the voice. The trachea in birds—even among species with short necks—is proportionately very much longer than in Man and many other mammals. The passage of musical sounds along a lengthened pipe would in itself enrich the tones and render them flute-like in character. Resilience was much enhanced through the marked elasticity of the tracheal membranes and the extraordinary manner in which the bony rings could approach and separate with great rapidity and suddenness. The rings not only made contact but their edges—which are distinctly bevelled—overlap with facility. The trachea when fully contracted was reduced to half its length. Emphasis was laid upon the fact that in many species this tube was capable of considerable distension. As it steadily contracted, vocal utterances, smooth and prolonged in character, were produced. In birds, the nasal chambers are too small and shallow, and the mouth, beak and tongue, too hard and rigid to influence the quality of the notes. Amplification and resonance had their seat almost entirely in the tracheal tube itself. Very high pressure of the current of air along the respiratory tracts, in many cases correlated with very strong sphincteric action of the musculature at the upper opening of the trachea, were factors which greatly aided powerful voice-production. But even when such mechanism was less developed, bird-language in many species, carried a long distance, seeing that purely musical tones entered into their composition. These, proving useful as an economic

factor in the bird's life, had become "Naturally Selected" to a surprising degree.

Professor WEST remarked on the immense time during which the lark's song seemed to be continued.

Professor PATTEN in reply said that the sound closely resembled that of a fishing reel. The duration had been timed and was from 30 seconds to a minute.

Dr A. B. APPLETON read a paper on "An example of the M. cervico-costo-humeralis (Grüber)," which will be published in the *Journal of Anatomy*.

Sir ARTHUR KEITH said that in his opinion the M. subclavius which in the Gibbon extends on to the humerus, is a migrated part of the original subclavius.

Professor PARSONS stated that the presence of such an abnormal muscle did not necessarily imply a "harking back" to a former type of muscle which had existed in remote ancestors of the species. In some cases there is an incomplete segmentation, e.g. in the present instance, the upper portion of the muscle corresponded to the scalene muscles, the lower part was subclavian. In the case of the rotator humeri, we have an example of a muscle which was useful in a former type of animal. Nature is carrying out a series of experiments—part of the scalene mass, blending with the coraco-brachialis muscle. The levator clavivulae is not concerned in the "make up" of this muscle. The levator claviculae acts in conjunction with the scapular head of the triceps; with regression of the long head of the triceps there is a disappearance of the levator claviculae.

Professor FRAZER remarked upon the difficulty in regarding "atavism" as an explanation of muscular anomalies. On an embryological basis they might be regarded as prolongations outwards from the lateral somatic mass.

Sir ARTHUR KEITH in reply to Professor Frazer said that embryological processes must be regarded as a reproduction of phylogenetic developments and were influenced by heredity.

Mr CECIL WAKELEY read "A note on the architecture of the ilium."

If the hip bone be manipulated it can be easily recognised that by far the thickest and strongest part of the bone is a bar which extends from the auricular surface to the acetabulum. This bar may be compared to a three-sided pyramid, the apex of which is situated at the upper part of the auricular surface; while its enormously thick base forms the upper part of the acetabulum. This thickened bar of bone obviously enables the hip bone to withstand the great stress of the body-weight transmitted from the sacrum to the head of the femur in the erect posture. There is further a second, but much less marked, thickening of the hip bone—extending from the tuberosity of the iliac crest, or projection on the iliac crest to which the ilio-tibial band is attached, to the upper part of the acetabulum. This thickening is again more or less pyramidal, and its base merges with that of the weight-resisting bar at the upper part of the acetabulum.

If a section be made through the hip bone in a plane corresponding to a line drawn from the upper part of the auricular surface to the acetabulum, it will be seen that the strength of the weight-resisting bar of bone does not depend on the actual thickness of the bone alone, but also upon a peculiar and remarkable arrangement of the bony material. In the cancellous tissue

two sets of pressure lamellae may be seen diverging from the auricular surface, and impinging upon two relatively very thick interjections from the surface of the compact bone on either side. The interjections of compact bone are comparable with the calcar femorale upon which the resistance of the inner side of the neck of the femur is so largely dependent. From these two interjections of compact bone spring two sets of lamellae which converge on to the upper part of the acetabulum, where again the compact bone is remarkably thick. There are thus two sets of lamellar arches in the cancellous bone interposed between the auricular surface and the acetabulum, inverted as regards one another, and supported by buttresses of compact tissue. A more adequate arrangement for resisting stress and strain cannot well be imagined. This peculiar cancellous tissue occupying the interval between the auricular surface and the acetabulum is sharply demarcated from the more or less round meshed cancellous tissue occupying the upper and hinder part of the bone, which is subject to the pull of muscles and ligaments, and does not directly resist the body-weight.

It is an interesting fact, which may be gathered from examining sectionised bones of young subjects, that the two supporting bars of the hip bone are not noticeable at birth, are obvious at the end of the first year, and become very distinct by the third year.

Certain well-known features of pelvic fractures now become intelligible.

Owing to the resistance which the bases of the two thickened bars of the hip bone confer upon the upper part of the acetabulum, fracture of the acetabulum, and especially of the upper part of the acetabular lip, are of relatively infrequent occurrence.

In most cases of fracture of the ilium the lines of fracture do not pass downward and forward from the point of application of the trauma, but invariably stop short in the region of the main bony bar.

Professor Parsons said that the posterior thickening of the bone represented the original ilium, the modifications in the anterior part represented a more recent response to a physiological need. The part in the neighbourhood of the tuberosity was the thickest part of the crest.

Professor Barclay-Smith said that although much labour and extended investigation had been spent on the intimate structure of such bones as the femur and the os calcis, little or no attention had been paid previously to the architecture of the hip bone. This, considering the functional importance of the bone, was a remarkable fact. The superimposed lamellar arches between the auricular surface and the acetabulum, which Mr Wakeley had described, presented one of the most beautiful and effective arrangements to be found in the skeleton.

Dr R. J. Gladstone read a paper on "The origin of the vena azygos major," and the development of the postrenal part of the inferior vena cava, with especial reference to the relations of the thoracic and lumbar azygos veins, and the course of the ascending lumbar veins. The paper will be published in the *Journal of Anatomy*. He also demonstrated a specimen of Persistent Left Subcardinal Vein, and other abnormalities of the abdominal veins. He showed sections of human embryos at different stages of development demonstrating the relation of the azygos veins and of the developing inferior vena cava to the sympathetic cord and splanchnic branches of the sympathetic.

Professor FRAZER said that a plexus of veins (periganglionic plexus) was developed around the nerve cords of the sympathetic system and that abnormalities of the abdominal veins were due to enlargement of certain channels in this plexus and the disappearance of others.

Dr TRIBE said that she had, with Dr Reagan, studied and reconstructed the abdominal veins in the rabbit in the earlier stages in which the posterior cardinal veins were still present. The later stages in the development of the abdominal veins were extremely complicated, and there seemed to be considerable differences in different types of animals.

Mr W. E. NEGUS read a paper on "The function of the Cartilages of Santorini." This will be published in the *Journal of Anatomy*.

Professor FRAZER enquired whether Mr Negus homologised the interarytenoid ligament (Lig. Interjugale) with the interarytenoid muscle. Mr Negus replied that he did not think there was a definite relationship between these two structures. He considered that the true function of the cartilages of Santorini was to give attachment to the ventral wall of the oesophagus, and thus assist the muscles of the larynx in opening the mouth of the oesophagus during deglutition.

Dr F. W. BRAMBELL read a paper on the "Histology of the gonads of an hermaphrodite pig." The paper is to be published in the *Journal of Anatomy*.

Professor FRAZER asked whether Dr Brambell considered that the sex of an animal was determined at the time of fecundation? or was it differentiated later?

Professor WRIGHT enquired whether hermaphroditism was more common in some animals than in others?

Dr BRAMBELL in reply to Professor Frazer's question said that the chromosomal characters of the nucleus were probably determined at the time of fertilisation. The male gonads are differentiated earlier than the female, and it is possible that they exercise an inhibiting influence on the development of the female characters. If the differentiation of the male gonads were delayed, it would be possible for the female characters to appear. In reply to Professor Wright he said that there were certain races or species of animals, and more particularly certain breeds of pigs in which hermaphroditism was much more common than in others.

Professor D. M. BLAIR read a paper on "The presence of deep submaxillary lymph glands in the substance of the submaxillary salivary gland." After a preliminary reference to the general position of the lymph glands in this region, and the presence of lymph glands in the substance of the parotid salivary gland, he alluded to the previous work of Neisse on the parotid glands and von Brunn and Bartels on the question of the presence of lymph glands in the submaxillary salivary gland.

His own investigations revealed the presence of lymph glands in the substance of the submaxillary salivary gland in some cases, but not in all. Stained serial sections of four submaxillary glands from young children were examined microscopically. Two of these showed no trace of any included lymph gland. In one a lymph gland of typical structure was found closely applied to its posterior pole, beneath the capsule of the salivary gland. In the remaining submaxillary gland a lymph node was found under the capsule, presenting still closer relations to the salivary tissue. Salivary acini were

seen invading the hilum of the lymph gland and lying scattered throughout its medulla, abutting in places upon the cortex. The invading acini were drained by a duct which passed out of the lymph gland to join another draining the adjacent part of the submaxillary gland.

Professor Blair commented also on the practical importance of the occasional presence of these deep lymph glands; surgically one cannot be sure of removing all submaxillary lymph glands without removing the submaxillary gland itself; pathologically these deep glands may be responsible for some occurrences of cancerous metastases in the salivary gland and they may be the real seat of the rare cases of apparently primary tuberculosis in the submaxillary gland.

Professor WRIGHT spoke of parotitis following abdominal operations. In olden days it was common for the mouth to get into a septic state, and it was generally supposed that the inflammation spread along Stenson's or Wharton's ducts and so reached the gland substance. It is possible however that the inflammation may have spread along the lymphatic vessels.

Mr DONALD showed "a specimen of an internal subperitoneal hernia," in which 16 inches of small intestine were strangulated within the sac.

FEBRUARY, 1929

AN ordinary meeting of the Society was held in St Thomas's Hospital Medical College on February 8th, 1929. The chair was first taken by the President and later by Professor Wright.

Dr E. P. STIBBE read a paper on "Sensory components of the motor nerves of the eye."

The nerves of the muscles of the eye are specially suitable for the investigation of the problems concerning afferent innervation of muscles, since afferent nerve-endings in these muscles are especially abundant and distinctive in type. There also seems to be a correlation between the size of the nerves and the precision of the movements for which they are responsible. Thus the inferior gluteal nerve is only three or four times the size of the abducens. Micro-tracings were shown demonstrating that in the full-time foetus the abducens nerve is actually as large as the inferior gluteal, while the ratio of weight of the gluteus maximus to the external rectus is 74 to 1. It is claimed by Chilba that the degree of refinement of movement of the muscles of the eye is a mathematical function of the number of motor fibres in the nerves supplying these muscles. For reasons such as these an investigation of the afferent fibres in the third, fourth and sixth nerves may be expected to be profitable.

The experimental work of Tozer and Sherrington led them to the conclusion that these nerves were afferent-efferent; the afferent paths were not to be found in the ophthalmic division of the fifth.

The writer is investigating the problem by means of dissections and serial sections of the cavernous sinus. Simple dissection is not very successful and use has been made of the macerating method practised by Rosenthal after Fruhwald. Various authorities who have described nerve-communications in the cavernous sinus and in the orbit were quoted.

Drawings and photographs were shown to illustrate the following points:

(1) That branches can be dissected out connecting the third, fourth and sixth nerves respectively with the ophthalmic division of the fifth.

(2) That these branches are composed principally of small fibres ($2\,\mu$–$5\,\mu$ in diameter); the larger of these fibres are in agreement with the size of afferent fibres as described elsewhere.

(3) That in the course of the third and sixth, communications are ganglion cells, sufficiently numerous to constitute definite ganglia.

The ganglion related to the sixth nerve is just behind the middle of the cavernous sinus, and is on the side of the carotid as the nerve crosses it.

The ganglion on the third-nerve communication is further forwards, close to the point where the ophthalmic division of the fifth nerve has given off its nasociliary branch, and is crossing the dividing third nerve.

Both these ganglia also receive fibres from the sympathetic trunks in their neighbourhood.

The nature of these ganglia is not yet ascertained. It is tempting however to regard them as groups of migrated posterior-root cells, seeing that such cells have been described in the course of the oculomotor nerves in other animals.

This paper is a preliminary report of investigations which will necessarily take a very long time before final conclusions are reached.

Professor J. P. Hill read a paper by Dr G. S. Sansom and himself on "Observations on the Structure and mode of Implantation of the Blastocyst of Cavia," of which the following is an abstract.

The observations of the authors, based on the examination of a series of blastocysts, prior to, during, and after implantation, essentially confirm the interpretation of the structure of the blastocyst which J. T. Wilson has put forward, after a critical review of the published descriptions and figures of Selenka, Spee and Maclaren and his own study of material in the Heape Collection at Cambridge (*Journ. of Anat.* vol. lxii), and they also demonstrate that implantation is interstitial as Graf Spee originally described and not excentric as Maclaren has recently (1926) maintained. The minute blastocyst (about $0{\cdot}06 \times 0{\cdot}06 \times 0{\cdot}04$ mm. in diameter) just prior to implantation, lies free in an antimesometrial enlargement of the uterine lumen and exhibits the normal Eutherian constitution, except that the zona has already disappeared, i.e. it consists of a complete investing layer of trophoblast, enclosing the blastocyst-cavity and also the inner cell-mass, situated in intimate contact with the covering trophoblast at the upper pole. As the first step towards implantation, the blastocyst so orientates itself that its lower pole comes into contact with the uterine epithelium, usually on the lateral side, sometimes at the base of the uterine bay. The uterine epithelium over the area of contact is destroyed and the lower polar region of the blastocyst first insinuates itself into the gap so formed and then the remainder of the blastocyst gradually follows. As the blastocyst imbeds itself, so the margins of the gap in the epithelium gradually approximate and finally meet and fuse over its upper pole. As the result, the blastocyst comes to occupy a subepithelial position in the uterine mucosa; its upper pole formed by the covering or ectoplacental trophoblast lies in immediate contact with the under surface of the now continuous uterine epithelium, whilst the remainder of its wall,

formed by the parietal trophoblast, is in contact with the decidual tissue of the corium.

During implantation, the covering trophoblast cells increase in size and divide to form the definitive ectoplacental trophoblast or Träger; the endoderm is differentiated as a continuous layer on the under surface of the spherical mass of amnio-embryonal ectoderm and soon passes into secondary continuity with the ectoplacental trophoblast; whilst the parietal trophoblast enters on the retrogressive changes which result in its disruption and eventual disappearance as a continuous membrane limiting the blastocyst cavity.

At the stage (S 1 *b*, 6 days) when rather more than the lower hemisphere of the blastocyst has passed through the gap in the uterine epithelium, the parietal trophoblast is already somewhat thickened and syncytial in character. Its inner surface, next the blastocyst cavity presents a definite sharp contour, its outer surface is more wavy and irregular. Its nuclei have increased in number and, where the layer is thickest, occur clumped together. In a slightly older blastocyst (S 6 *b*, 6$\frac{1}{2}$ days), the parietal trophoblast has increased still more in thickness and just below its junction with the ectoplacental trophoblast has sent out more or less extensive solid, wing-like extensions, lying immediately below the uterine epithelium. Its nuclei have become much more numerous and lie crowded together either as a continuous series or in groups. They stain on the whole more deeply than those of the rest of the blastocyst.

By the time the gap in the uterine epithelium is nearly closed (S 3 *c*, 6$\frac{1}{4}$ days), the changes in the parietal trophoblast are greatly accentuated. Though it is still continuous with the thickened ectoplacental trophoblast and still forms a complete boundary to the blastocyst cavity, it is now very obviously syncytial in character, appearing as a quite irregular layer, thinner over the lower polar region but very much thicker equatorially where it reaches a considerable extension below the uterine epithelium and consists for the most part of sponge-like vacuolated cytoplasm, the boundary between which and the surrounding decidual tissue is frequently quite indefinite. In it are situated numerous nuclei, mostly densely aggregated together in larger and smaller groups.

In the blastocyst of 7 days, striking advances are seen. The ectoplacental embryonal mass has increased greatly in size, measuring about 0·1 × 0·07 × 0·06 mm. in diameter and is roughly oblong in section. Its upper half consists of ectoplacental trophoblast, closely attached to the under surface of the uterine epithelium, its lower half, of the spherical mass of amnio-embryonal ectoderm, closely invested by the single thick layer of endoderm which is now in direct continuity above with the ectoplacental trophoblast. The mass projects into an irregular space, simulating a decidual cavity but really representing the blastocyst cavity of earlier stages, considerably enlarged. It is incompletely bounded by a more or less discontinuous and ragged syncytial zone of considerable but very varying thickness, in which occur numerous vesicular nuclei, mostly densely aggregated together to form relatively large clumps and readily distinguishable from those of the surrounding decidual cells. This zone represents the greatly hypertrophied and degenerate parietal trophoblast which has now lost all connection with the ectoplacental mass, and that it is actually in retrogression is proven not only by its cytological characters but by the fact that maternal capillaries have penetrated into it. It is a noteworthy fact that once the gap in the uterine epithelium

has been formed, the parietal trophoblast in Cavia exhibits no further evidence of functional activity, destructive or other, the hypertrophic growth of its cytoplasm and the enormous increase in the number of its nuclei being but the signs of retrogression and the prelude to its ultimate dissolution.

At the 8-day stage, when the endoderm has elongated to form a closed cylinder, at the bottom of which the solid amnio-embryonal mass is situated and which is continuous at its upper end with the attaching ectoplacental trophoblast, the remains of the parietal trophoblast are still recognisable in the form of irregular strands and masses containing numerous small deeply staining nuclei, situated along the sides and bottom of the irregular cleft-like cavity in the decidual tissue into which the embryonal cylinder projects.

Our observations accordingly demonstrate (1) that the free blastocyst of Cavia has the normal Eutherian structure, (2) that, with all its parts intact, it implants itself in the uterine mucosa by penetrating directly through the uterine epithelium, its lower pole constituting the "implantation pole," (3) that the parietal trophoblast has only a transitory existence and in correlation therewith, never possesses a lining of endoderm, (4) that Spee's "Saftraum," Maclaren's "destruction space," is, to begin with, none other than the blastocyst cavity.

We suggest that under the peculiar conditions arising out of the interstitial mode of implantation, the so-called "inversion" of the endoderm and the growth of the latter to form an elongated cylinder may be interpreted as an adaptive device which enables the yolk-sac splanchnopleure to participate directly and at the earliest possible moment in the establishment of the yolk-sac placenta.

Professor W. E. Le Gros Clark read a paper on "A method of demonstrating lymphatic plexuses."

Professor Hill commented on the practical importance of the Prussian blue method, and the likelihood of its proving useful in other regions than in the nasal mucous membrane.

Mr Burne enquired whether the Prussian blue was found on the surface of the vessels, or whether it actually entered the lumen.

The President spoke of the obvious importance of the method in connection with absorption into the subarachnoid space, and the spread of disease from the upper part of the nasal cavities.

Professor Jamieson enquired whether Professor Le Gros Clark had used the method in any other situation than the nasal mucous membrane, e.g. the urethral mucous membrane.

Professor Le Gros Clark said that the work was in an experimental stage. That communications existed along the course of the olfactory nerves by which the tissue spaces of the nasal mucous membrane were connected with the subarachnoid space. The fluid could pass from the spaces in the nasal mucous membrane into the subarachnoid space and as had been shown by Weed from the subarachnoid space into the venous sinuses and nerve tissues.

Dr H. A. Harris read a paper on "The diploic veins as evidence of age, with especial reference to the skull attributed to Lord Darnley."

Radiograms of skulls of known age were exhibited in order to indicate clearly the radiographic pattern of the meningeal vessels on the one hand and of the venous sinuses of the diploë on the other. The meningeal pattern

persists with but little change from adolescence to old age, but the diploic pattern appears slowly in the third decade, reaches a maximum (at the age of maximum efficiency) in the fifth decade and then gradually disappears. This change in the pattern of the diploic vessels resembles the age changes in the dimensions of the inner, outer and diploic layers of the skull. In old age the diploë is absorbed and the skull reverts to a structure which is almost as distinctly free from diploë as the skull of the child of five years. The inner table or vitreous displays the most profound senile and pathological changes in extreme old age. The cyclical changes in the diploë are to be correlated with the cyclical age changes in the mandible. Sections of various skulls of known age were shown in confirmation of the radiographic picture.

The skull of a young adolescent presenting a gumma of the parietal bone was shown with radiograms to indicate the nature of the inflammatory response in bone to chronic infection. Chronic inflammation of bone displays a central area of rarefaction with a surrounding zone of bony condensation. No such areas of ante-mortem reaction are seen in the actual skull attributed to Lord Darnley or in the radiograms thereof.

Radiograms of the synchondrosis between the basi-occiput and basi-sphenoid in skulls of about 21 years were shown and compared with radiograms of the Darnley skull.

The skull attributed to Lord Darnley by Professor Karl Pearson and Sir Arthur Keith cannot be accepted as genuine in view of the well-developed venous sinuses of the diploë, the fusion of the basi-cranial axis and the absence of inflammatory response in the bones.

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KEITH, Sir ARTHUR (1928). "The Skull of Lord Darnley." *Brit. Med. Journ.* Sept. 8th, pp. 456–7.

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Dr H. A. HARRIS read a paper on "The growth of the long bones in foetal life," to be submitted for publication in the *Journal of Anatomy*.

Professor F. G. PARSONS read papers on (i) "The position of the external auditory meatus," (ii) "The thickness of the living scalp." These papers will be published in the *Journal of Anatomy*.

Mr A. J. E. CAVE exhibited:

(1) An axis vertebra with absent costal element (cervical rib).

The specimen was taken from a student's adult half skeleton of continental origin, in which the cervical column includes the bones of more than one individual; but the second, third, sixth and seventh cervical vertebrae and the rest of the presacral part of the column belong to the same skeleton. The middle dorsal region exhibits a marked scoliosis with the concavity to the left, due to asymmetry of D.V. 5. The body of this vertebra is wedge-shaped, being only half as deep on the left as on the right. It occupies the deepest part of the scoliotic curve, which is completed by the bodies of D.V. 4, 6 and 7, these vertebrae being considerably modified in shape and alignment. There is no suggestion of absent half vertebra in the case of D.V. 5, the scoliosis being undoubtedly due to pathological or static causes.

In the second cervical vertebra, all parts are present and normal, except the left transverse process, which, save for the most medial portion of the posterior root, is entirely absent.

A tiny conical bony spicule (now somewhat damaged through handling), which arises from the front of the left pedicle represents the posterior limb of the transverse process: the tubercle and the anterior root are altogether wanting.

There is, however, evidence to suggest that, during life, the parts now lacking (i.e. the costal element of the vertebra) were present, and present, moreover, not in the form of fibrous tissue, but as a detached piece of bone, thus constituting, in effect, a cervical rib on the axis vertebra.

The evidence is as follow. Immediately below the lateral edge of the left superior articular process, on the axis body, is situated a blunt tubercle which, at first glance, might suggest the stump of a broken ordinary anterior root. Close inspection, however, reveals three facts against such conclusion:

(1) The tubercle is not continued into a bayonet- or needle-shaped spicule, as is usually the case when one root of a cervical transverse process is replaced by ligament,

(2) its surface is not jagged or rough (i.e. not a fracture surface), but is

(3) smooth and almost polished, very strongly suggesting that it was an articular surface, for the medial extremity of the detached rib element. In the absence of this latter, of course, no *absolute* proof can be forthcoming as to the original condition of the parts, but the appearances indicated are presumptive evidence in favour of the view expressed.

Whilst Le Double (*Traité des Vars. de la Col. Vert., etc.*, 1912) records complete absence of the posterior root of the axial transverse process in 0·92 per cent. cases (6 in 650 bones) and incomplete absence in 2·3 per cent. cases (19 in 800 bones), nowhere does he instance a single case of absence of the anterior root, either from his own investigations or from the literature: nor does he mention a cervical rib in connection with the second vertebra.

As is well known, the costal element of C.V. 7 very frequently—if not constantly—develops from an independent ossific centre, and remains free from its vertebra in at least 1 per cent. adult skeletons. More frequently than is usually suspected, separate costal centres appear in the upper cervical vertebrae, though more rarely giving rise to accessory ribs; such centres have been described by Blandin (*Nouv. élém. d'anat.* 1838) for C.V. 3, 5, 6; by Meckel (*Handbk. Hum. Anat.*) for C.V. 2, 5, 6, 7; and by Theile and Hyrtl for C.V. 4 and 5.

Definite cervical ribs on C.V. 6 have been noted by Karg, Beck (*Ann. Surg.* 1905), Le Double (*op. cit.*), Rosenberg (*Sitz. der Natur. Ges. zu Dorpat*, 1882), and Struthers (*Journ. Anat. and Phys.* 1875). Paul Albrecht (*Bull. de Mus. Roy. D'Hist. Nat. Belge*, 1882) found them in a young hippopotamus. Czerny (quoted by Volcker, *Beitr. z. Klin. Chir.* 1898) described a feebly developed rib in connection with the fifth cervical, though this case must be accepted with reserve, since the rudimentary rib formed the pedicle of a partially ossified lipoma.

On C.V. 4 cervical ribs have been discovered by Fischel (*Anat. Hefte*, 1906), Szawlowski (*Anat. Anz.* 1901), and Whyte (*N.Z. Med. Journ.* 1927), whilst Halbertsma (*Virchow's Archiv*, 1857) has mentioned a third cervical possessing a rib. Nowhere in the literature at my command have I found

record of an axis vertebra bearing an independent rib, consequently the present specimen, if the interpretation given be correct, is unique.

(2) Fusion of third and fourth cervical vertebrae.

Specimen 1. The partially fused C.V. 3 and 4 from a male column with formula C. 7, D. 12, L. 5, S. 5, Co. 4 (natural). Fusion is by the spines, right laminae and articular pillars, and is complete. X-rays reveal no demarcation line. Bodies, left pillars and laminae are separated by the normal intervertebral structures. The bony piece is somewhat asymmetrical, the third vertebra being pressed down on to the fourth, especially on the right side: the laminae of C.V. 4 are un-united dorso-medially and the feebly developed right fourth lamina is incorporated with its cranial neighbour. The half of the fourth spinous process attached to the left lamina is exaggerated.

Specimen 2. The completely fused C.V. 3 and 4 from an adult male with a normal vertebral formula. All parts of both bones are present: fusion is by bodies, articular pillars, laminae and spines. There is no asymmetry. X-ray examination reveals remains of a disc between the two centra, but of no other intervertebral tissues.

It is suggested that in Specimen 1 the fusion occurred either before birth or not later than the first year. In Specimen 2 it is difficult to decide with certainty whether (*a*) pre-existing intervertebral structures have been removed by absorption and if so, at what date, or (*b*) whether the greater part of such structures failed to appear at all.

(3) Anomalies of sixth cervical vertebra in Man, Orang and *Macacus*.

Specimen 1. Cervical column of adult male. Vertebral formula = C. 7, D. 12, L. 5, S. 5: no other anomaly. Right transverse process of C.V. 6 well formed, with typical tubercles, but imperforate. Vertebral artery enters the fifth cervical. Left transverse process normal, as are processes of the remaining cervical vertebrae.

Specimen 2. Cervical spine of 56 year old male. Vertebral formula = C. $6\frac{1}{2}$, D. 12, L. 5, S. 5, Co? Right half of C.V. 3 congenitally absent and remaining half fused with the axis by body, pedicle, lamina and spine. Transverse processes intact on the left, but on right those of C.V. 1, 5 and 7 are chipped: that of the fourth vertebra being also so deficient anteriorly that the vertebrarterial canal is open. (A chipped osseous stump, projecting from the pedicle represents part at least of the posterior root: a vertical ridge projecting laterally from the body corresponds to part of the anterior root: remainder of lateral process has been ligamentous.)

Transverse processes of C.V. 6 typical in size and shape, with vigorous anterior tubercles, but both imperforate. Vertebral artery impresses upper border of anterior root of each process in its cranio-dorsal ascent to hole in transverse process of C.V. 5.

Specimen 3. Sixth cervical vertebra of adult male. No details of rest of column available. Specimen normal and typical save for right transverse process, which is imperforate and peculiar. Left transverse process has typical roots and tubercles, a foramen for the vertebral artery and a small posterior hole for the vein. On right side the posterior root and tubercle are present, but the costo-transverse lamella, anterior root and tubercle (i.e. the costal element) are suppressed: there is no arterial foramen. A ridge running from the neuro-

central lip to the pedicle serves for muscle attachment, and functionally replaces the suppressed element.

Specimen 4. Complete cervical spine of adult Orang (Birm. Univ. Anat. Dept.—kindly loaned by Professor Brash). Upper five vertebrae normal: C.V. 7 shows tendency to assume dorsal characters—e.g. bilateral demi-facet for first rib, bilateral absence of anterior root of transverse process and well-developed posterior root.

C.V. 6 has asymmetrical transverse processes. The right is typical and perforate, though the foramen appears too small to have transmitted the vertebral artery. The left process lacks the costo-transverse lamella, and the two roots are exaggerated and divaricate more widely than those of the right side, probably owing to the shifting on to them of the musculature usually attached to the costo-transverse lamella.

Specimen 5. *Macacus rhesus.* Upper six cervical vertebrae. Posterior root of right axial transverse process ligamentous. C.V. 6 has right transverse process imperforate, with a marked arterial depression on ventral surface of base of the anterior root, caused by the vertebral artery ascending to the fifth vertebra.

Dr E. P. Stibbe and Dr F. Davies demonstrated:

(1) Complete absence of the quadratus femoris muscle.

The left thigh of an aged subject showed a wide gap between upper border of adductor magnus and lower border of inferior gemellus. In the gap were seen the obturator externus and the dividing medial circumflex artery, the quadratus femoris being completely absent. The nerve to the quadratus femoris coming from the front of the great sciatic nerve was much reduced in size. It divided to supply the inferior gemellus and entered the back of the hip joint.

It is suggested that the absence of the quadratus femoris in contradistinction to its incorporation or fusion with the inferior gemellus is a rare condition.

(2) Bursal cyst in subscapularis?

The specimen showed a cyst in the distal part of the muscular belly of the subscapularis. The cyst was $1\frac{1}{4}$ inches long by $\frac{1}{2}$ inch in diameter tapering a little at its distal end. The wall was tough but not thick. The contents were thick glairy fluid like synovia. The cavity did not communicate with the shoulder joint. The normal subscapularis bursa was present.

As the shoulder joint was quite healthy, and the cyst stripped readily out of the muscle without the need for dissection, and there were no cysts or other anomaly in any other part of the body—the cyst in question would appear likely to have been an adventitious bursa, though we are at a loss to explain its existence.

MAY, 1929

An ordinary meeting of the Society was held at the London Hospital Medical College on Friday, May 3rd, 1929, first the President and subsequently Professor Johnston were in the chair.

A paper was read by Professor Walmsley on "A Diverticulum from the Appendix Caeci," which has been submitted for publication in the *Journal of Anatomy.*

Professor PARSONS suggested that the deformity might be explained on the assumption that the caecum is originally double, and one segment is normally suppressed, but that in certain cases both segments may be developed.

Professor WALMSLEY said he knew of no reference to a case of double caecum in the human subject.

Professor WRIGHT said that the case might be regarded as an example of a duplicated organ such as "diphallus."

Professor WALMSLEY also read a paper on "An Abnormal Shoulder Joint."

The specimen was obtained from a male infant aged 8 months who was the subject of hydrocephalus, cleft palate, spina bifida, club foot, and syndactyly of fingers and toes. The hip joints were normal; but the shoulder joints, both of which are similarly formed, show a remarkable reversal of the normal curvatures. The head of the humerus appears to be absent, the humeral articular facet is flat from above downwards and concave from side to side; the scapular facet is reciprocal in shape. The tuberosities of the humerus are normal and have the usual muscles attached to them; the brachial plexus is normal in its arrangement. The condition may represent the development of the joint cleft below the articular epiphysis of the humeral head and the incorporation of this epiphysis in the scapula. X-ray examination gives no confirmation of this hypothesis, that is, there is no humeral capitular ossific centre on the scapula, and such an incorporation is indeed difficult to conceive.

Professor WRIGHT showed a specimen of a "Two-chambered heart." The paper will be submitted for publication in the *Journal of Anatomy*.

Professor JOHNSTON, speaking of the difficulty which had been found in determining which was the front and which was the back of the heart, gave it as his opinion that the atrial surface in which the large veins terminated was the dorsal aspect.

Professor WALMSLEY agreed with Professor Johnston with regard to the identification of the posterior aspect, the primary opening of the pulmonary veins being into the sinus venosus. Single ventricles are very rare. The septum may lie very near one wall of the ventricle, and the cavity of one ventricle be small but not entirely absent. He suggested that in the case which was exhibited, the interventricular septum might be applied to the wall of the left ventricle.

Professor Walmsley also commented on the position of the node of Tawara—whether it was to be regarded as a sinus structure, or without the sinus on the septum.

Professor FAWCETT was inclined to agree with Professor Walmsley's opinion with regard to the fusion of the interventricular septum with the left wall of the ventricle.

Professor PARSONS read a paper entitled "Some observations on Jutish Skulls," which will be published in the *Journal of Anatomy*.

Professor LE GROS CLARK referring to the types of prognathism described by Professor Parsons as alveolar prognathism, and to metagnathism, said that considerable variations occurred in individuals belonging to the same race, and suggested that the Grimaldi skulls which have been generally regarded as negroid in type might be an individual (or familial) variation.

Professor WRIGHT remarked on the extreme degrees of variation which

are sometimes produced as a result of morbid conditions, e.g. variations in the mode of breathing. Mouth-breathers having high arched palates, and small nasal cavities.

Professor FAWCETT enquired what was the sex of the skull? whether it was female? and remarked on the influence of sex upon the facial part of the skull.

Mr C. DONALD read a paper on "Diphallus" which will be submitted for publication in the *Journal of Anatomy.*

Mr RALPH THOMPSON referred to a case of double penis below an ectopia vesicae. It was difficult to decide in some cases whether the organ is a penis or clitoris. In extreme cases of perineal hypospadias there is as a rule a large glans. He doubted whether these cases of deformity of the external genital organs were related to defective development of the primitive streak.

Professor FAWCETT said that it was not necessarily the whole of the primitive streak which was involved, a part only might be concerned.

Professor LE GROS CLARK read a paper on the "Anatomical Routes by which Infection may pass from the Nasal Cavities to the Brain."

The general trend of the discussion which followed was to the effect that Professor Le Gros Clark had clearly demonstrated the ease with which fluids can be absorbed from the olfactory mucous membrane into the intracranial subarachnoid cavity and into the olfactory lobes, and the danger of injecting poisonous fluids into the upper part of the nasal cavities: also the danger of absorption of infective material in inflammatory and suppurative conditions of the nasal mucous membrane.

Professor BLAIR enquired what was the actual path by which absorption took place. Was it through tissue spaces? or through cells? Certain substances can circulate in the vascular system generally, but there is a barrier preventing the fluid passing into the ventricles of the brain or subarachnoid space.

There appeared to be a grave danger in treating purulent affections of the nose by strong disinfectant solutions, that not only might poisonous effects be produced in the brain by the solution, but that purulent matter might be sniffed up into the upper parts of the nasal cavities where it might be absorbed.

Mr RALPH THOMPSON referred to cases reported by Mansell-Moullin of the extension of inflammation from facial boils to the meninges.

Professor YEATES alluded to cases of disseminated sclerosis in which organisms absorbed through the nose, were believed to be the cause of the disease. The ependyma was invaded and the sclerotic process spread outwards into the nerve tissue.

Professor LE GROS CLARK in reply to Professor Blair said that absorption took place by direct continuity, without there being any cellular barrier. This had been confirmed by Weed and other investigators.

Mr R. RUTHERFORD, introduced by Dr R. J. Gladstone, read a paper on "A case of undescended testicle associated with uterus and Fallopian tube."

The case was that of a child aet. 2 years admitted to King's College Hospital, on account of a swelling in the left inguinal region, which proved to be a hernia.

The external genitalia were those of a male, but no testes were palpable.

The child was remarkably like a girl, so much so that the Padre who was about to perform the christening ceremony thought it was a girl he had to deal with.

Operation disclosed a uterus, Fallopian tubes, and two sex glands occupying the position of the ovaries. A portion of the tube with a sex gland were removed for examination.

Histological features:

1. The sex gland was a testis with an epididymis.
2. A much dilated vas deferens with thin walls was present.
3. The tunica albuginea was seen to be invaded by cords of cells which had a resemblance to the cellular elements of the body of the testis. Large cells resembling genital cells could be seen both in the cells forming the seminiferous tubules, and in the invaded part of the tunica.
4. The seminiferous tubules were non-canalised, except in the neighbourhood of the mediastinum. Interstitial cells were scanty and small. The gland was thought to be ill-developed although of normal size.
5. The epididymis was normal.
6. A normal Fallopian tube, 2 mm. in diameter.

With regard to the invasion of the tunica reference was made to a similar case brought to the notice of the Society by Dr Brambell, and three suggestions were discussed:

(*a*) Was the invasion malignant?
(*b*) Was it an invasion from the periphery of ovarian germinal epithelium?
(*c*) Was this a case of sex reversion, with the recessive female element becoming dominant as evidenced by the undoubted female appearance of the child, and the dominant male element becoming recessive as shown by the ill-developed seminiferous tubules?

A similar case was quoted of a French soldier, aet. 31 years; serving at the "Front," who was operated on for left inguinal hernia. Uterus, tubes and testes occupying the usual position of the ovaries were found in the sac. One of the testes examined was found to contain spermatozoa. His ejaculated semen contained active spermatozoa. He was married and his wife had given birth to two children. He exhibited no external female characters and never had menstrual pain.

Bibliography. Couvelaire and Duclaux (1918–19). *Ann. de Gynec. et d'Obstet.* p. xiii.

Mr Hume alluded to the case of a "woman" operated on for inguinal hernia. The genital gland on examination proved to be a testis. There was a well-developed vagina and a small cervix uteri. The clitoris was large and not canalised. The pelvis was of masculine rather than of female type. The "woman" had been married for seven years. He presumed that the other genital gland was also a testis.

Dr Brambell regarded these cases as genetically males, and being due to an abnormal arrest of development. The condition was most common in pigs. The structure of the gonads was of the same class with that of the true hermaphrodite pigs. There appeared to be a delay in the male stimulus, accompanied by a slight growth in the female direction, then the male element predominates again. A few cases have occurred in which ovarian tissue is actually present in the testis.

Dr Gladstone said that these cases of sex-intergrades which occur in the human subject, pigs and other animals, and also cases of sex reversal

raise fundamental issues with regard to (1) the theory of the continuity of the germ cells, and the relation of these to the somatic cells, (2) the chromosomal constitution of the nucleus of the male and female gametes and of the somatic cells.

If peritoneal epithelium in the male such as that covering the tunica albuginea of the testis is capable of giving rise to ovarian tissue containing ova in well-defined Graafian follicles, what is the chromosomal constitution of the nuclei of these ova? It is obvious that these cases have an important bearing on the current views on sex determination and heredity.

The point which Mr Rutherford raised with regard to the growth of tumours in imperfectly descended testes was also of great practical importance. A study of the mode of commencement and the histological structure of such tumours might yield valuable results with regard to the growth of tumours in general.

Dr H. A. HARRIS read papers on (1) "The Vascular supply of bone," (2) "Cystic Ovary in a Babe." These papers will be submitted for publication in the *Journal of Anatomy.*

Mr HUME raised the question as to whether the bone was invaded by the vessels? or whether the vessels became included in the growth of the bone?

Mr HARRIS in reply stated that in necrosis of bone invasion is from the periphery; there are no central vessels. Analogous conditions were present in gummata and tubercle. There is a limit to the size of a gumma, when this is reached degeneration of the matrix occurs, followed by invasion of vessels. The same occurs in tubercle, and in epiphyses, e.g. the lower end of the femur.

JUNE, 1929

THE summer meeting of the Society was held in the School of Medicine, Newcastle-on-Tyne, on Friday, June 21st and Saturday, June 22nd, 1929, the President being in the chair.

Mr J. WHILLIE exhibited a specimen showing "an unusually large thyroidea ima artery."

The vessel arose from the anterior surface of the innominate artery in the usual position. Both inferior thyroid arteries were small.

The ascending cervical artery on each side arose directly from the thyroid axis.

Mr WHILLIE also read a paper on "The arrangement of the fibres of the palato-pharyngeus and superior constrictor muscles," which will be submitted for publication in the *Journal of Anatomy.*

Professor JOHNSTON said that the well-marked ridge shown in some of the specimens appeared to be produced by a definite palatine constrictor. In cases of cleft palate it is probably hypertrophied.

The PRESIDENT congratulated Mr Whillie on the excellence of the dissections and the lantern slides showing the appearance of the pharynx and soft palate in side view. He doubted whether the aponeurosis of the tensor palati muscle represented the morphological aponeurosis of the soft palate.

Mr J. Gilmour, introduced by Professor Green, read a paper, on "Obstruction of the urethra by Prostatic Valves," which will be submitted for publication in the *Journal of Anatomy*.

Professor Johnston enquired whether there was any instance of distension of the prostatic utricle in the cases described. Mr Gilmour in reply stated that there was one such case.

Dr Gladstone said that the valvular folds might arise in connection with the opening of the Wolffian ducts into the urogenital sinus at the side of the Müllerian eminence.

Dr R. D. Lockhart read papers on (1) "The movements of the normal shoulder joint and a case with paralysis of the Trapezius studied by radiogram and experiment." (2) "Complete Double Aortic Arch." Both papers will be submitted for publication in the *Journal of Anatomy*.

Professor Johnston said that in considering the movements of the shoulder joint a distinction must be made between movement outward of the lower end of the humerus in a plane transverse to the trunk, and movement in the plane of the scapula which forms a considerable angle with the transverse plane of the trunk.

Dr J. Beattie gave a review of some recent work on "The higher sympathetic centres in the Diencephalon." This work has been carried out by Dr Long, Dr Brow and himself at McGill University. Dr Beattie demonstrated that there are cell groups in the hypothalamic region of the brain, lying in the lateral wall and floor of the third ventricle near the ependyma. From these cells pass out fibres which descend and end around the anterolateral columns of grey matter of the thoraco-lumbar spinal cord. The connections of the cell masses with other regions of the cerebrum have not been worked out completely, but there is some evidence that fibres from the pyriform lobe pass to them by way of the medial fore-brain bundle. The experimental evidence which was presented showed that sensory stimulation can influence these centres by a direct thalamo-hypothalamic pathway, probably from the medial nuclei of the thalamus.

The bearing of the work on certain physiological problems was discussed and the hypothesis suggested that these cell masses form the "motor cortex" of the sympathetic nervous system.

Professor Le Gros Clark asked the exact region of the pyriform lobe to which degenerated fibres had been traced. Prof. Beattie replied that he thought most of the fibres ended in the more ventral and medial part of the pyriform area.

Professor D. M. Blair asked whether Professor Beattie could throw any light on the sympathetic innervation of skeletal muscle. Professor Beattie replied that he had no evidence to present which was sufficiently definite to be of any value.

Professor D. Waterston enquired whether injury of the pituitary gland had any possible effect on the experiments described by Professor Beattie. In reply it was stated that the work of Bailey and Bremer had shown that many of the so-called "pituitary symptoms" in hypophysectomised animals were due to hypothalamic lesions. Hypophysectomy did not interfere with the results demonstrated by Dr Beattie.

Professor WATERSTON asked whether these "centres" had any effect on insulin secretion. Dr Beattie stated that the evidence pointed towards either no effect, or an inhibitory one.

In discussing other parts of the paper Professor Waterston enquired as to the criterion of sympathetic activity and integrity used in the experimental work. It was stated in reply that any one of the following changes in the heart's action could be regarded as due to the removal of sympathetic control of that organ.

(1) Decrease in rate.
(2) Increase in the auriculo-ventricular conduction time.
(3) Abolition of an extra-systolic arhythmia induced by chloroform anaesthesia.

The reverse effects could be produced by stimulation directly of the sympathetic pathway to the heart, or by the injection of adrenalin.

Professor LE GROS CLARK read a paper on "The Anterior Nuclei of the Thalamus in Insectivores." Three elements of the anterior group of thalamic nuclei were recognised, anterodorsal, anteroventral, and anteromedial nuclei. The differential development of these elements shows a great degree of variation within the limits of the insectivora. Each element, where it is well developed, is found to be directly related to the termination of the mamillothalamic tract. The anteromedial nucleus is to be regarded as a palaeothalamic nucleus, while the other two nuclei are neothalamic. The great development of the anterodorsal element in Macroscelides is associated with the unusual extent of the area retrosplenialis of the cortex, and recalls a similar combination in the brain of rodents generally. It was thought that this association has some bearing on Kappers' suggestion that the anterodorsal element is in direct fibre connection with the retrosplenial areas of the cerebral cortex. The anterodorsal element is hardly represented in the primitive mammalian brain of *Erinaceus* and is to be regarded as essentially a mammalian character which becomes highly developed in certain groups such as the Macroscelididae and, to a lesser extent, in the rodents. The anteroventral and anteromedial elements, on the other hand, were homologised with the nucleus dorsolateralis anterior and the nucleus dorsomedialis anterior of the reptilian thalamus.

Dr BEATTIE quoted a case of tumour involving the region of the third ventricle, and destroying the anteromedial nuclei of the thalamus. This produced marked symptoms, the chief of which were epilepsy, sweating, rise of blood-pressure, acceleration of the heart's action, increase of adrenalin secretion, and sleep. The attacks recurred once or twice a day. The patient died with the heart in a state of ventricular fibrillation.

Professor FRAZER demonstrated some reconstruction models, and drawings showing embryonic formations in the telencephalic floor.

Professor LE GROS CLARK enquired whether the blood-vessels supplying the hypothalamus and thalamus were derived from the anterior or from the middle cerebral artery.

The PRESIDENT asked how the claustrum was isolated? Was it by the growth of projection fibres?

Professor FRAZER in replying said that the arteries supplying the hypothalamus came off about the point where the carotid artery bifurcated into the anterior and middle cerebral arteries. He could not give a definite statement with regard to the origin of the claustrum.

Professor C. M. West described "Two unusual abnormalities of the flexor pollicis longus." The first case was associated with a large median artery which took part in the formation of the superficial palmar arch. In both cases there was a slip from the flexor pollicis longus passing downwards and fusing with the index tendon of the flexor profundus at the origin of the first lumbrical. In the first case the slip appeared to be a continuation of the condylar head of the flexor pollicis, to which it was attached by a few transverse muscle fibres. In the second case the tendinous slip was attached by muscle fibre to the anterior surface of the radius below the flexor pollicis, under which it passed to its attachment to the index tendon of the profundus. Professor West showed drawings of dissections of the flexors of the digits in *Ornithorrhyncus*, *Lutra vulgaris*, *Phocaena communis*, *Tupaia* and *Cynocephalus*, and suggested, by comparison with the arrangement in these animals, a possible cause of the condition described in the two cases found in the human subject.

Dr F. Davies read a paper on the "Conducting System of the Heart," which will be submitted for publication in the *Journal of Anatomy*.

Dr Beattie said that Dr Davies's paper was an excellent example of the relation of physiology to structure. It supplied an important structural basis for the physiological phenomena. The very rapid conduction of the impulses raised a doubt as to whether or no the conduction was entirely through muscle. The valves are actually contracted from the start. In the humming bird the heart's beats are 400 per minute. A recurrent branch given off from the vagus in front of the aorta, as in the human subject, can be frequently recognised in birds, and there is a rich nervous connection in the aortic region. Tawara left the conducting system of the bird's heart incompletely worked out. Dr Davies was to be congratulated upon his valuable communication on the subject.

Mr A. J. E. Cave exhibited a "Skull showing a cranio-pharyngeal canal and asymmetrical maxillary sinuses." The paper will be submitted for publication in the *Journal of Anatomy*.

The President said that there appeared to be an independent ossification of the clinoid processes. He was doubtful whether the foramen represented a true craniopharyngeal canal or not.

Dr Beattie said that two syndromes could be distinguished in connection with enlargement of the pituitary body. One type in which the optic phenomena are developed very rapidly, and one in which the onset is more gradual. The difference possibly depended on the thickness of the bony wall. The growth might originate in the craniopharyngeal canal, or extend from the pituitary fossa into the canal or sphenoidal sinus. It is probable that the entrance of filterable viruses into the cranial cavity in cases of encephalitis lethargica is through the nasal air sinuses.

Professor Green enquired whether the mass occupying the cavity in front of the pituitary fossa described by Dr Beattie was a purely new growth, or whether it originated from pituitary tissue primarily lying within the cavity. Dr Beattie replied that the cell elements were very much changed, and it was difficult to say whether they were a new growth or a process of the pituitary body.

Dr F. Davies demonstrated the following specimens on behalf of Dr E. P. Stibbe.

1. "Right lung showing only one fissure."

This was a right lung from a dissecting-room subject, an aged male. It consisted apparently of two lobes only; the oblique fissure occupied its average position, except that on the mediastinal surface it approached less nearly to the root of the lung than usual.

The transverse fissure was absent, and there was absolutely no indication on the surface of the lung of any attempt at its formation.

The lung was healthy and the pleura absolutely free from adhesions.

Dissection of the bronchi and vessels showed that the eparterial bronchus was present an inch from the bifurcation of the trachea, and was large; it supplied the greater part of the upper lobe. The first hyparterial bronchus was smaller than the usual bronchus of the middle lobe, was ventral in position, and supplied a limited territory in the lower part of the upper lobe adjacent to the root of the lung.

Though anomalies of the lobes of the lungs are very common, those in the direction of diminution in number of lobes are less frequent than increase in the number. Hepburn reported a right lung showing apparently only two lobes, in which the first hyparterial bronchus was reduced and supplied a partly isolated buried middle lobe situated close to the root of the lung. He explains the condition as due to an early arrest of growth of the bud destined to form the middle lobe; and from the exact resemblance of the hyparterial bronchial branching of right and left sides, he regards the case as demonstrating that the apical and basal lobes of the left lung correspond to the middle and basal of the right.

Hepburn was unable to find any record of complete absence of the right middle lobe of the lung, or of such reduction in its size and fusion with the apical lobe, and adds that he has never seen anything of the kind in a long experience.

On these grounds the present case seemed worth a brief report.

2. "Lateral thoracic branch of the internal mammary artery."

This condition was found in the body of an aged male subject in the dissecting-room of University College, London.

The internal mammary artery gave off a large branch which crossed the front of the apex of the lung to reach the first rib at about its middle. Thence the artery ran down between the pleura and the lateral thoracic wall, gradually getting smaller but not disappearing till the ninth space was reached. In each space it gave off well-marked though small anterior and posterior intercostal arteries which anastomosed with the internal mammary and aortic intercostals respectively.

In the first space two very large lymph glands were found along the artery, and smaller lymph nodes in the second and third spaces. The artery was accompanied by veins which joined the internal mammary vein.

The internal mammary artery itself was not reduced in size. It followed a normal course, divided behind the sixth cartilage, and gave off its usual branches. The lateral thoracic artery from the axillary was present, but was reduced to a tiny vessel. Pectoral axillary lymph glands were present at the lower border of the pectoralis minor.

The arteries of the left side showed the same arrangement even to the extent of a very notable symmetry.

This lateral thoracic artery from the internal mammary is well known, and has been reported by Hepburn. The present case is perhaps of special interest in respect of the following features:

(1) The internal mammary artery takes a lateral course in certain animals; this is not however a replacing artery but a supplementary one.

(2) The symmetry is unusual.

(3) The artery replaces the lateral thoracic artery.

(4) The special interest lies perhaps in the lymph glands. These in a female would almost underlie the axillary tail of the breast, and the lymph vessels draining into them would almost certainly include efferents from the lateral part of the mammary lymphatic field. The deduction from this in respect of mammary cancer is obvious.

Professor GREEN showed a specimen of "An abnormal cavum septum pellucidi." The septum had two laminae each of which was so extensively perforated that the cavity communicated freely with the lateral ventricles. The cavum was about 1·5 cm. in width, and extended the whole length of the corpus callosum. There was a communication also with the third ventricle just behind the lamina terminalis.

He also exhibited a series of dissections of the brain mounted for use in the museum.

A blunt dissection of a brain hardened by one of the ordinary methods was made with an "orange stick." The brain was then kept for a few days in spirit, and afterwards for two weeks in glycerine and water 50 per cent. The specimens were painted with weak gelatine, and in some cases with coloured gelatine. The colours employed, e.g. vermilion and yellow ochre were insoluble in glycerine or water. The dissections were mounted in 50 per cent. glycerine and water.

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